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OCTOBER, 1925

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PULMONARY ATELECTASIS, WITH ESPECIAL REFERENCE TO MASSIVE COLLAPSE OF THE LUNG*

EDWARD D. CHURCHILL, M.D.

BOSTON

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INTRODUCTION

In a consideration of clinical phenomena, the application of a new and unfamiliar name to a special phase of a well known pathologic condition may add complexity and confusion rather than increased clarity, and serve to isolate it from allied conditions which share certain fundamental relationships. The term massive collapse, originated by Pasteur, is unfortunate in this respect, since it has led to a neglect of the clinical and experimental data on the general subject of pulmonary atelectasis. It is true that Pasteur considered that massive collapse of the lung differs from lobular or patchy collapse and partial deflation, but he based this differentiation on its etiology; and as the causal factors of all these conditions are obscure, many writers differing radically from Pasteur's theory, it has seemed desirable to review the subject of pulmonary atelectasis as a whole. It is believed that the so-called massive collapse of the lung, which has been receiving increasing attention as a postoperative pulmonary complication, is but a special type of pulmonary atelectasis, and that, at least in the majority of instances, it occurs as a result of the same etiologic factors.

*From the surgical services of the Massachusetts General Hospital.

HISTORY

The term *atelectasis* was constructed by Jörg,[1] in 1832, do denote the state of imperfect expansion of the lungs which occurs in new-born infants as a persistence of the fetal condition. Previous to this, Louis [2] (1829) is quoted by West as having found in nineteen out of forty-six patients who had died of typhoid fever, a condition of the lungs which he termed "carnification." It is evident from his description that this condition was identical with the areas of atelectasis later described as occurring so frequently in children.

Legendre and Bailley [3] (1844) noted in the lungs of infants dying of pulmonary catarrh or, more rarely, of nonpulmonary disease, areas which were similar in texture to the lungs of infants that had never breathed. These areas could be expanded by insufflation, and are described as a return to the airless condition of the fetal lungs. This condition, these authors showed, had previously been seen and described by several other observers, although its true nature had not been recognized. As of importance in etiology, in addition to the pulmonary catarrh and the enfeebled state of the patient, are mentioned mechanical factors, such as tight binders, which restrict respiratory movements, and prolonged dorsal decubitus. To Legendre and Bailley must be given the credit for the clear demonstration of the nature of atelectasis by the simple procedure of tracheal insufflation, although this experiment had been tried by Troccon,[4] in 1814, in lungs showing deficient expansion due to edema. For an excellent survey of the early history of the progress of knowledge with reference to atelectasis in infancy and childhood, the papers of Gairdner [5] and of Willshire [6] may be consulted.

Gairdner [5] (1853) recognized that "collapse of the lung, whether in the lobular or diffused form is an exceedingly common lesion in the adult," and that in its essential characters it is similar to the lesion so frequently met with in children. He believed that its production depended on the following causes: "Firstly, the existence of mucus in the bronchi; secondly, weakness or inefficiency of the inspiratory power, however caused; thirdly, inability to cough and expectorate, and thus to remove the obstructing mucus." The mucus was thought to produce collapse by the ball-valve action which would mechanically result from an obstructing pellet in a series of tubes of diminishing caliber, such as the bronchi.

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1. Jörg: Diss. Lipsiae, 1832, quoted by Lord.
2. Louis: Recherches sur la gastro-entérite, Paris **1**:361, 1829, quoted by West, p. 321.
3. Legendre and Bailley: Arch. gén. de méd., 1844, pp. 55, 184, 286.
4. Troccon, J. A.: Paris, 1814, quoted by West, p. 325.
5. Gairdner, W. T.: Brit. and For. Med., Chir. Rev. **11**:453, 1853.
6. Willshire, W. H.: Brit. and For. Med., Chir. Rev. **12**:514, 1853.

Bartels [7] (1861) called attention to atelectasis as a complication of the pulmonary sequelae of measles. He was the first to suggest that the air was absorbed by the blood, and believed that the blocking of the bronchioles by secretion was the important factor in etiology.

Lichtheim [8] (1878) as a result of extensive experiments rejected the ball-valve theory of Gairdner, and concluded that the atelectasis following bronchial occlusion was produced by the absorption of the residual air by the blood stream. In a discussion of these experiments, Sewall [9] admits that it was proved that the air may be absorbed by the blood, but calls attention to the fact that Lichtheim did not disprove the possibility that the air cells may also be emptied through the ball-valve action of a bronchial plug. He further suggests that the more rapid collapse which was obtained when the chest was closed rather than left open after producing bronchial obstruction was due to the slight contraction and expansion of the lung then produced by the respiratory movements. This could scarcely have been a factor, however, in the animals in which a tight ligature was applied to the bronchus, thus entirely excluding any possible ball-valve action. Lichtheim explains the difference by the drying of the parts in an open pneumothorax. Further explanation may be found in the work of Hess,[10] who found that at least a 30 per cent. decrease in the volume of the pulmonary circulation resulted from chilling the surface of the lung.

West [11] (1884) devotes the greater part of two chapters in his "Diseases of Infancy and Childhood" to a consideration of atelectasis. He cites cases to show that collapse involving large areas of the lungs may take place suddenly in enfeebled children, the incident being definitely marked by dyspnea and prostration. The condition is produced, he believes, by feebleness in inspiratory power, which is unable to overcome the obstacle of mucus blocking the bronchi.

W. Pasteur [12] (1890) observed partial and complete collapse of the lower lobes of the lungs in a series of cases of diphtheric paralysis of the diaphragm. A second paper [13] was published, in 1895, with the addition of cases, bringing the number that had been under his observation to a total of thirty-two. A more elaborate exposition of his theory of the mechanism of this collapse was developed later with his observations on postoperative cases; at this time, however, he suggested that the collapse of the pulmonary tissue was due to a loss of function

7. Bartels: Arch. f. path. Anat. **21**:129, 1861.
8. Lichtheim: Arch. f. exper. Path. u. Pharmakol. **10**:54, 1878.
9. Sewall, Henry: Am. Rev. Tuberc. **4**:811 (Jan.) 1921.
10. Hess, R.: Deutsch. Arch. f. klin. Med. **106**:489, 1912.
11. West, C.: Diseases of Infancy and Childhood, Ed. 7, London, 1884.
12. Pasteur, W.: Am. J. M. Sc. **100**:242, 1890.
13. Pasteur, W.: Tr. Clin. Soc., London **28**:111, 1895.

directly dependent on the diaphragmatic paralysis. Previous to this work of Pasteur's, Pearson-Irvine [14] had, in 1876, described a case of diphtheric paralysis of the muscles of the upper portion of the thorax in which there was collapse of the apexes of the lungs. He believed that, in addition to the paralysis of the thoracic muscles, there also was present a paralysis of the muscles of the bronchi, which in some manner aided in the production of the pulmonary collapse.

Dixon and Brodie [15] (1903) carried out extensive experiments on the action of the bronchial muscles, measuring their reactions by the volume changes in a lobe of the lung enclosed in an oncometer. By this method, bronchoconstriction and bronchodilatation were produced both through the action of drugs and by direct and reflex vagal stimulation. The particular point of interest in relation to atelectasis is that they were able to produce either distention or collapse of the lung by varying the force of inflation and the time allowed for deflation. With rapid, forceful artificial respiration allowing a short time for expiration, bronchoconstriction commonly produced distention. With a less forceful artificial respiration, and an interval sufficiently long to allow full expiration, constriction of the bronchioles resulted in collapse. A lobe collapse in such a manner usually remained so after the bronchoconstriction had passed off.

Sir James Barr [16] (1907) was the first to describe a case of collapse of the lung occurring as a postoperative complication. He states,

> My colleague had removed some tuberculous glands from the right iliac fossa in a youth. A few days after the operation the boy got an oscillating temperature, and although there was no respiratory distress it was found that the right side of the chest was . . . absolutely dull from base to apex with absence of respiratory murmur and no vocal phenomena. I rapidly came to the conclusion that the right pleura was full of fluid, which I thought should be drawn off, although there was no urgent necessity for interference.

On failing to find fluid the correct diagnosis of atelectasis was made, and the youth recovered "under a course of respiratory gymnastics."

Barr had also seen atelectasis in typhoid fever, endocarditis, pyemia and other prolonged illnesses, and believed that the condition was caused by the negative pressure falling "to a low ebb.' In his experience, it was particularly apt to occur in young, flat-chested individuals with pliant chest walls.

Turning his attention to postoperative complications, Pasteur [17] was the first writer to recognize that collapse of the lung is a not infrequent

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14. Pearson-Irvine, J.: Tr. Clin. Soc., London **9**:188, 1876.
15. Dixon, W. E., and Brodie, T. G.: J. Physiol. **29**:97, 1903.
16. Barr, J.: Brit. M. J. **2**:1289, 1907.
17. Pasteur, W.: Lancet **2**:1351, 1908; ibid. **2**:1080, 1910; ibid. **1**:1329, 1911; Brit. J. Surg. **1**:587, 1914.

occurrence after major operations, particularly abdominal sections. He considers that this collapse is a distinct entity, in no way similar either in nature or origin to the partial deflation or patchy collapse met with in other conditions. To differentiate it from these other forms of atelectasis, Pasteur chose the term *massive collapse* or *active lobar collapse*. His definition of the term is "total deflation of a large area of lung tissue, of sudden onset—in the absence of any signs of obstruction of the airway or of any known cause of compression—due to failure of inspiratory power and attended by physical signs and symptoms." Subsequent authors have added very little to Pasteur's description of the signs and symptoms of postoperative collapse of the lung, although his theory as to its causation is open to question.

Reasoning from his observations in postdiphtheric paralysis of the diaphragm, he considers that "whenever—whether as the result of paralysis or of reflex inhibition of muscular action—the distending force acting on the lungs becomes less than that of the elastic and muscular agencies which tend to cause its contraction, the latter, so to speak, take charge, with the result that the affected portion of the lung rapidly empties itself of its contained air." These conditions, he believes, are met with most frequently with a loss of the mobility of the diaphragm, either by direct paralysis or by reflex inhibition from acute inflammation or pain in its immediate neighborhood. It is on this conception of its etiology, rather than from a consideration of the lesion itself, that he considers massive collapse to differ from the other more well known forms of pulmonary atelectasis.

Elliott and Dingley [18] (1914) report eleven cases of postoperative collapse, calling particular attention to the presence of mucopurulent sputum and fever in all instances under their observation. In a brief discussion regarding etiology, they conclude that collapse is a result of the combined action of obstruction of the bronchioles by inflammatory edema and secretion and reflex immobility of the diaphragm. As will be shown later, they clearly point out that bronchial obstruction is essential for the production of massive collapse.

Briscoe [19] (1914), in a short communication, takes issue with the conclusions of Elliott and Dingley, pointing out that the collapse of the lower lobes is a natural sequence of prolonged quiet breathing in the supine position in such patients as do not use the abdominal muscles to fix their chests. Later this idea was elaborated in a more extensive study [20] (1920), the conclusion of which is not greatly different from the theory of Pasteur. While the latter author considers the immobility

18. Elliott, T. R., and Dingley, L. A.: Lancet **1**:1305, 1914.

19. Briscoe, J. C.: Lancet **1**:1502, 1914.

20. Briscoe, J. C.: Quart. J. Med. **13**:293 (April) 1920.

of the diaphragm to be due to reflex arrest, Briscoe believes in an actual inflammation of the muscle or of its pleural surface, and also emphasizes the importance of posture and the configuration of the chest in the individual subject.

Bradford [21] (1917, 1919) observed a number of cases of massive pulmonary collapse following war wounds, and in particular drew attention to contralateral collapse following trivial injury of the chest wall. In many of his cases, there was no expectoration at any stage in the disease, and sometimes no urgent symptoms. Although he admits that the factors of etiology are obscure, Bradford inclines to the belief that the immobility and retraction of the chest wall are active rather than passive, and primary instead of secondary to the collapse of the lung. The mechanism of the production of this condition of the chest wall is thought possibly to be of reflex nervous origin. He believes that bronchial obstruction either from spasm or secretion cannot be regarded as a causal factor in the variety of collapse met with following war injuries.

Scrimger [22] (1921) reports seven cases of postoperative massive collapse of the lung occurring in a series of 540 operations on male patients. In all cases, the onset was within the first twenty-four hours, and was marked by the characteristic signs and symptoms, of which he considers the displacement of the heart the most important. Mucoid sputum was present early in all the cases of this series. He believes that the condition may be brought about by a contraction of the muscular elements in the lung through reflex vagal control, aided by a subsequent collection of mucus which prevents the passage of air beyond the obstruction. Absorption of the alveolar air then follows.

Sewall [9] (1921) gives a comprehensive review of the subject of pulmonary atelectasis without mentioning, however, its occurrence as a postoperative complication. His historical consideration is excellent. From a study of the experimental literature, he inclines to the belief that atelectasis is produced by the valvular action of bronchial mucus. It is also noted, however, that in clinical conditions a deficiency in inspiratory force and depth nearly always accompanies its presence.

Hirschboeck [23] (1922) reports three cases following laparotomies, with necropsy findings in one. He believes that limitation of respiratory movements favors the collection of mucus in the smaller bronchioles, with resultant obstruction to the ingress of air. Alveolar absorption then leads to collapse of the pulmonary tissue. Either bronchial obstruction or limitation of respiration may predominate in the individual case.

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21. Bradford, J. R.: Bull. et mém. Soc. méd. d. hôp. de Paris **41**:719, 1917; Quart. J. Med. **12**:127, 1919; Oxford Loose-Leaf Medicine **2**:127.

22. Scrimger, F. A. C.: Surg., Gynec. & Obst. **32**:486 (June) 1921.

23. Hirschboeck, F. J.: Am. J. M. Sc. **164**:268 (Aug.) 1922.

Elwyn and Girdansky [24] (1922) present in detail a case of massive collapse of the lung following operation for stab wound of the abdomen. The roentgenograms reproduced show the typical findings with complete return to normal in a month. Elwyn [25] (1922, 1924), in studies of postoperative pulmonary complications at the Mt. Sinai Hospital, reports further cases of massive collapse as of not uncommon occurrence. He believes that large or small areas of atelectasis are found quite frequently following operations, and that in the presence of bronchitis, either preexistent or caused by the anesthetic, these areas of collapse predispose to the development of pneumonia. He does not attempt to explain the occurrence of the areas of atelectasis.

Gwyn [26] (1923) found eighteen cases of massive collapse of the lung in two years. He also mentions displacement of the heart in cases of pneumonia as indicative of atelectasis. The obscure etiology is commented on, and it is suggested that vasomotor disturbance of the pulmonary circulation may be a causal factor.

Lord [27] (1915) devotes a very interesting chapter in his textbook to the subject of atelectasis, and points out the fact that varying degrees of collapse occur not infrequently in suppurative lesions of the lungs. In a discussion of Gwyn's paper,[28] he states that displacement of the heart toward the lesion was found in fourteen out of 558 cases of pneumonia. He believes the process to be of inflammatory origin, the atelectasis being secondary to exudation in the bronchi. Wallgren [29] (1923) also has found a shifting of the heart and mediastinum to the diseased side in a large percentage of cases of pneumonia in infants, and calls attention to the importance of this finding in the exclusion of pleural effusion.

Leopold [30] (1924), basing his observations on four cases of postoperative collapse, believes because of the extreme density of the pulmonary tissue, as shown by roentgen-ray examination, that there is more than simple massive atelectasis present. To explain this finding, he suggests that the lung also is "drowned," borrowing the term and its pathologic significance from the bronchoscopic studies of Chevalier

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24. Elwyn, H., and Girdansky, J.: Postoperative Massive Collapse of Lung, J. A. M. A. **79**:718 (Aug. 26) 1922.

25. Elwyn, H.: Postoperative Pneumonia, J. A. M. A. **79**:2154 (Dec. 23) 1922; Postoperative Pneumonia, ibid. **82**:384 (Feb. 2) 1924.

26. Gwyn, N. B.: Massive Collapse of the Lung, Tr. A. Am. Phys. **38**:411, 1923; abstr., J. A. M. A. **80**:1803 (June 16) 1923.

27. Lord, F. T.: Disease of the Bronchi, Lungs and Pleura, Philadelphia, 1915.

28. Lord, F. T.: Massive Collapse of the Lung, abstr., J. A. M. A. **80**:1803 (June 16) 1923.

29. Wallgren, A.: Acta Paediatrica, Upsala **3**:81, 1923.

30. Leopold, S. S.: Am. J. M. Sc. **167**:421 (March) 1924.

Jackson. Complete bronchial obstruction is considered by Leopold to be the best explanation for the cause of the condition.

Lee [31] (1924) reports two cases of massive collapse, and discusses the importance of varying degrees of pulmonary collapse in the etiology of the pneumonic forms of postoperative pulmonary complications. This author believes with Elliott and Dingley that two factors—bronchial obstruction and arrest of the respiratory muscles—combine in the production of collapse. He also suggests that collapse of the lung, in varying degrees, attends any operative procedure and any traumatic or inflammatory injury of the chest and trunk which may cause inhibition of normal respiratory movements by pain or posture.

Other case reports of massive collapse of the lung have appeared by Eccles [32] (1911), Tidy [33] (1914), Crymble [34] (1918), Scholtz [35] (1921) and Ritvo [36] (1924).

CLINICAL OBSERVATIONS

The following cases illustrate some of the important phases of postoperative pulmonary atelectasis, or massive collapse of the lung, observed during the last two years in the surgical services of the Massachusetts General Hospital. Six typical cases of massive collapse have occurred as postoperative complications during this period, and several cases of atelectasis associated with other clinical conditions have been observed which seem to throw further light on the problem. As the roentgenographic findings of some of the cases of massive collapse have been described elsewhere by Dr. George Holmes,[37] that aspect of the subject will be only briefly mentioned.

POSTOPERATIVE MASSIVE COLLAPSE

CASE 1.—V. S., a woman, aged 20, a stenographer, gave no history of past or present respiratory infection, and a preoperative roentgen-ray examination of her chest was negative. A left oophorectomy and right salpingo-oophorectomy with routine appendectomy were performed for bilateral multilocular adenocystomas. The operation was quite difficult, and attended by some shock. Ether anesthesia, with gas induction, was employed. During the operation, the respirations were rapid, shallow and irregular, with excessive mucus, and on the evening of the following day there was a sudden rise of temperature, pulse and respiration, accompanied by dyspnea. Examination showed a limited excursion of the right chest, with flatness to percussion and diminished breath sounds below the clavicle. The heart was displaced to the right. The next

31. Lee, W. E.: Ann. Surg. **79**:506 (April) 1924.
32. Eccles, McAdam: West London M. J. **16**:282, 1911.
33. Tidy, H. L., and Phillips, E.: Lancet **1**:1245 (May 2) 1914.
34. Crymble, P. T.: Brit. J. Surg. **5**:363 (Jan.) 1918.
35. Scholtz, C. J.: M. J. South Africa **16**:202 (June) 1921 .
36. Ritvo, Max: Am. J. Roentgenol. **11**:337 (April) 1924.
37. Holmes, G. W.: Am. J. Roentgenol. **10**:509, 1924.

day, the condition was better, and she was raising a small amount of purulent sputum showing pneumococci and streptococci. Sonorous râles were present throughout the lungs, and below the angle of the scapula, on the right, there was bronchial breathing, ægophony, increased voice sounds and normal tactile fremitus. A roentgenogram (Fig. 1), taken two days after the operation, showed increased density of the right chest, especially at the base, displacement of the heart and mediastinum toward that side, narrowing of the intercostal spaces and a high position and hazy outline of the right half of the diaphragm. The temperature rapidly came to normal; the sputum ceased, and the patient was discharged on the ninth day. At this time, a roentgenogram (Fig. 2) showed

Fig. 1.—Condition two days after operation.

the heart still displaced to the right, and the diaphragm high and fixed. The position of the latter was defined by a small amount of air remaining in the peritoneal cavity after the operation. The triangular area of dulness in the lung field above the diaphragm has sharply defined borders, and represents the collapsed lower lobe.

Case 2.—J. B., a man, aged 51, a Jewish baker, postponed his admission two weeks because of a cold, but was free from cough and sputum at the time of operation. A right inguinal hernia was repaired under ether anesthesia, the respirations being noted as irregular and shallow. The second day following the operation, he had a slight cough with the production of a small amount of thin sputum. That evening he was awakened by a choking sensation, which

recurred with repeated spells of dyspnea during the night. On examination, the following morning, he showed limitation of the respiratory excursion of the right chest, with displacement of the heart to the right. There was diminished resonance throughout the right chest with flatness at the base; the breath sounds were diminished at the apex and absent elsewhere; vocal and tactile fremitus were unchanged except for diminution at the base and there were

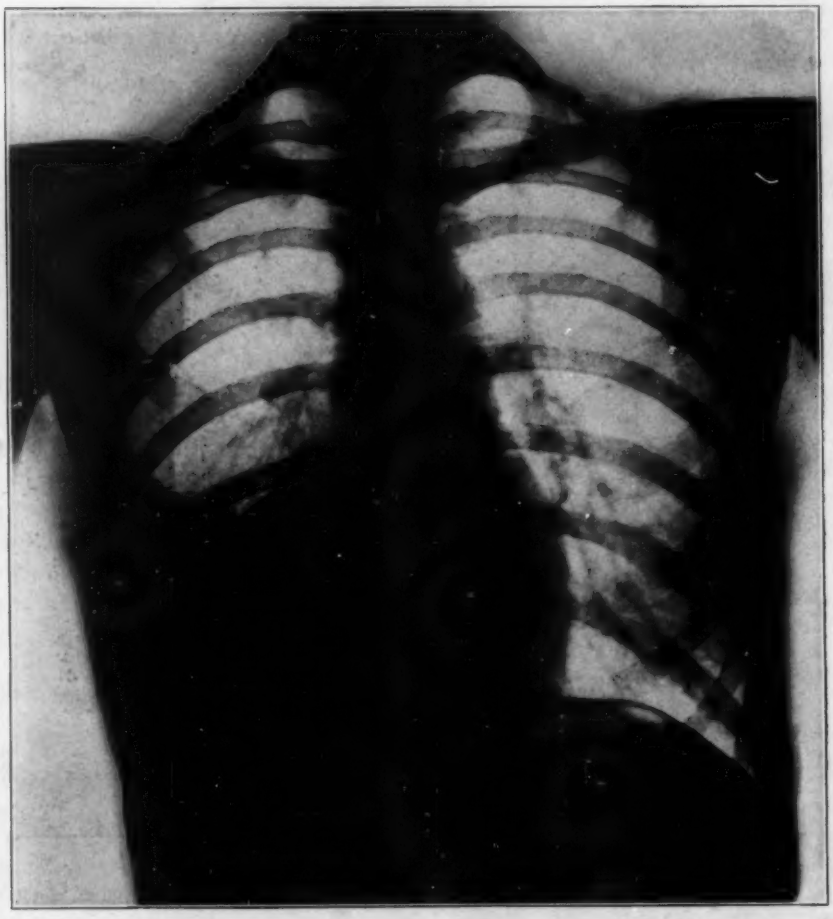

Fig. 2.—Condition of same patient as in Figure 1 seven days later at time of discharge; the outline of the diaphragm is indicated by the small amount of air above the dome of the liver—presumably a small pneumoperitoneum predominant organism.

no râles. The small amount of purulent sputum showed a pneumococcus to be the predominant organism.

The roentgenogram confirmed the diagnosis, and is reproduced to show the typical triangular area of marked density with its apex rising toward the hilum of the lung, and its outer angle fusing with the shadow of the diaphragm (Fig. 3). This should be compared with the second plate of Case 1 (Fig. 2),

in which the outline of the diaphragm was fortunately delineated by the small pneumoperitoneum. The patient rapidly improved; the temperature soon returned to normal, and a roentgen-ray examination, at the time of discharge, showed reexpansion on the right lung (Fig. 4).

CASE 3.—G. R., a man, aged 28, a laborer, had a slight cough before the repair of a ventral hernia under ether anesthesia. The following day, a sharp rise in temperature and pulse was attended by cough and a purulent sputum. Examination showed that the excursion of the right chest was limited, with eversion of the costal margin on inspiration. There was dulness throughout

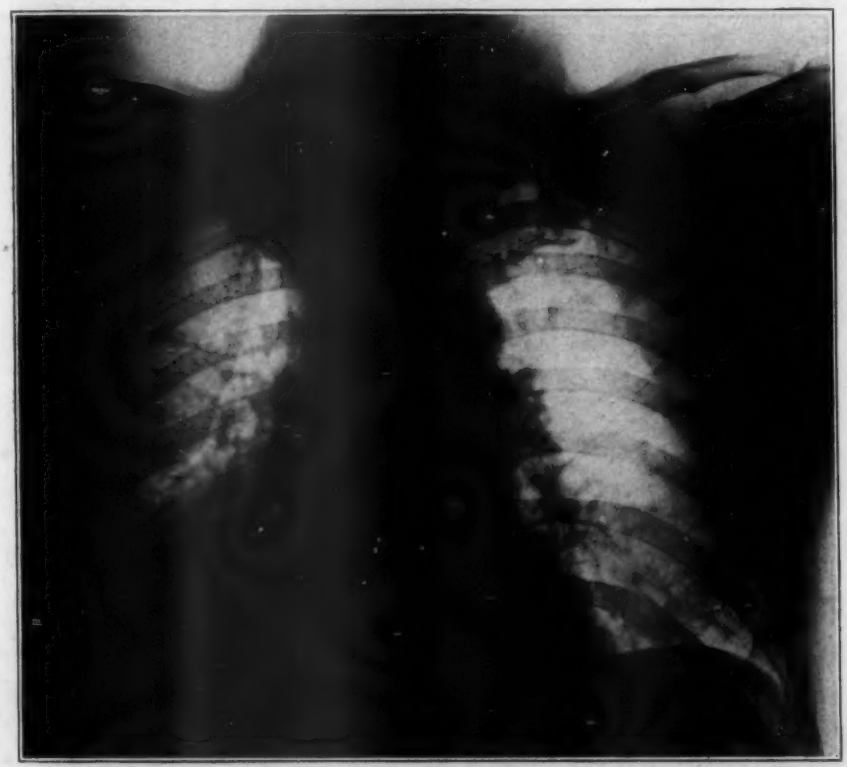

Fig. 3.—Condition three days after operation; the upper border of the collapsed right lower lobe is seen as a well defined line rising toward the hilum medially, and fusing with the shadow of the diaphragm laterally.

the right chest, with diminished vocal and tactile fremitus, but no râles. Displacement of the heart to the right was confirmed by roentgen-ray examination, the plate of which presents a picture more like that described by Leopold as "massive collapse and drowned lung" than any of the others in this series (Fig. 5).

CASE 4.—G. G., aged 19, a healthy young man, had a subacute appendix removed under ether anesthesia. He coughed considerably, during recovery from the anesthetic and on the following day, but otherwise his convalescence was normal until the second day, when he had a chill, with the onset of

marked dyspnea and cyanosis. Physical examination at that time showed limitation of the excursion of the right chest with eversion of the costal border. The right chest was dull throughout, with diminished breath sounds, and in the region of the angle of the scapula there was a patch of loud bronchial breathing and egophony, with increased tactile fremitus. There were no râles. The heart was displaced to the right. A moderate amount of purulent sputum showed pneumococci of Type III. A roentgen-ray examination showed increased density throughout the right chest except at the extreme apex, and confirmed

Fig. 4.—Condition of same patient as in Figure 3 nine days later, showing the normally curved outline of the diaphragm as contrasted with the shadow in Figure 3.

the displacement of the heart and mediastinum to the right. The respiratory embarrassment soon disappeared; the sputum lessened in amount, and, on the sixth postoperative day, the temperature reached normal and remained so.

Case 5.—T. C., a school boy, aged 14, gave a history of frequent head colds and asthmatic attacks during each winter and hay-fever in the summer. He had had a cough two weeks before admission. A small indirect left inguinal hernia was repaired under procain infiltration, the operation being completed in forty minutes. During the next two days, the temperature was slightly elevated, and he had some abdominal discomfort. On the third day, his

respirations rose to forty a minute, with apparent air-hunger and a frequent unproductive cough. On examination, the right chest was immobile and the interspaces narrowed. Anteriorly, there was dull tympany with absent breath and voice sounds. Posteriorly, at the base, the chest was flat, with absent breath sounds, vocal and tactile fremitus. In the region of the hilum, there was an area of hyperresonance with bronchial breathing and increased voice sounds. There were no râles. The heart was displaced to the right judging by physical signs, and extremely so, judging by roentgen-ray examination (Fig. 6), which

Fig. 5.—Extremé roentgenographic density, commented on by Leopold and believed to indicate a "drowned" as well as atelectatic lung.

also confirmed the collapse of the right lung. The temperature was higher the following day, with a leukocytosis of 25,400. A small amount of purulent sputum contained Type IV pneumococcus. Subsequently, the temperature returned to normal, and a series of roentgenograms showed the gradual return of the heart and mediastinum to their normal position.

Case 6.—D. S., a man, aged 40, a chauffeur, postponed his admission ten days because of an acute upper respiratory infection. A repair of a bilateral inguinal

hernia was then performed under epidural (sacral) anesthesia. Cough and purulent sputum began almost at once after the operation, and the following day the temperature rose to 102 F., with a leukocytosis of 20,000. There was no pain, chill or noticeable respiratory embarrassment. Examination of the chest showed dulness throughout the right side, most marked at the base, with diminished breath sounds and tactile fremitus. Below the angle of the scapula, there was a small area of bronchial breathing with coarse râles. Roentgen-ray

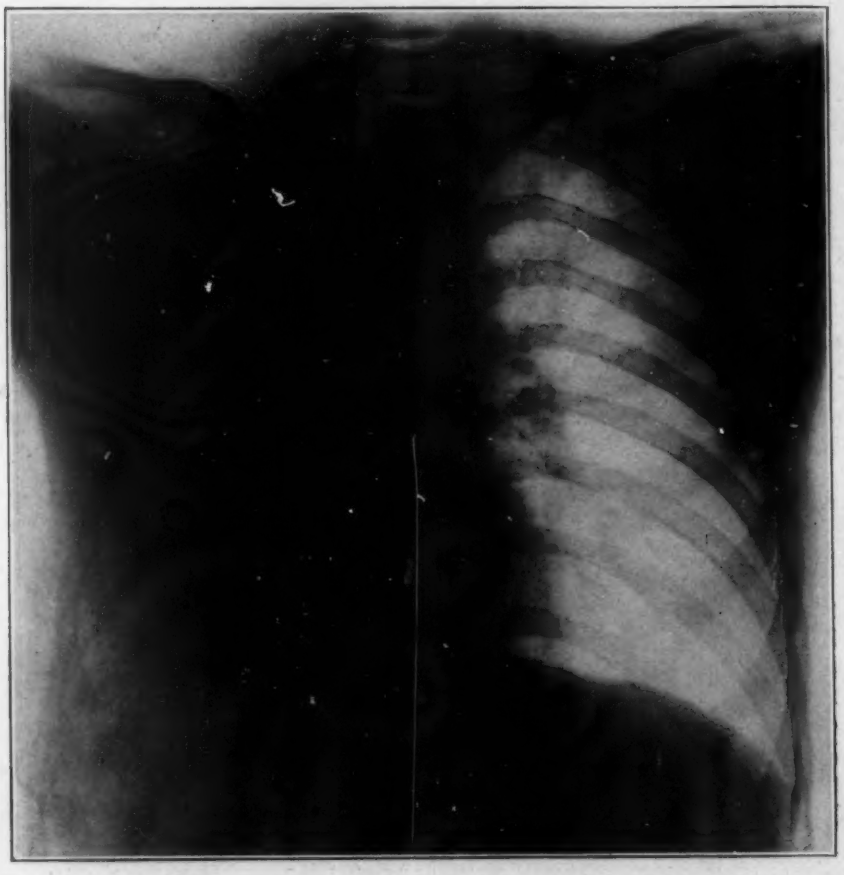

Fig. 6.—Condition three days after operation: almost complete collapse of the right lung; outline of the trachea displaced to the right, probably accounting for the auscultatory signs in Figure 11.

examination showed narrowing of the interspaces on the right side, with a high diaphragm and displacement of the heart to that side. The entire right lung field was less radiant than the left, with mottled dulness at the base. A cough with purulent sputum containing pneumococci persisted for several days; otherwise, his condition rapidly improved, and he was discharged on the sixteenth day.

COLLAPSE FOLLOWING PARALYSIS OF THE INTERCOSTAL MUSCLES

CASE 7.—M. B., a woman, aged 52, sustained a fracture of the cervical spine with almost complete transverse myelitis at the level of the fifth cervical segment. There was a resulting loss of reflexes, sensation and motor function below this segment, complete except for slight movement in both biceps. This lesion, of course, produced paralysis of all the intercostal and abdominal muscles, the respiratory movements being purely diaphragmatic. She remained under observation for nearly two weeks, and died shortly after dischage from the hospital.

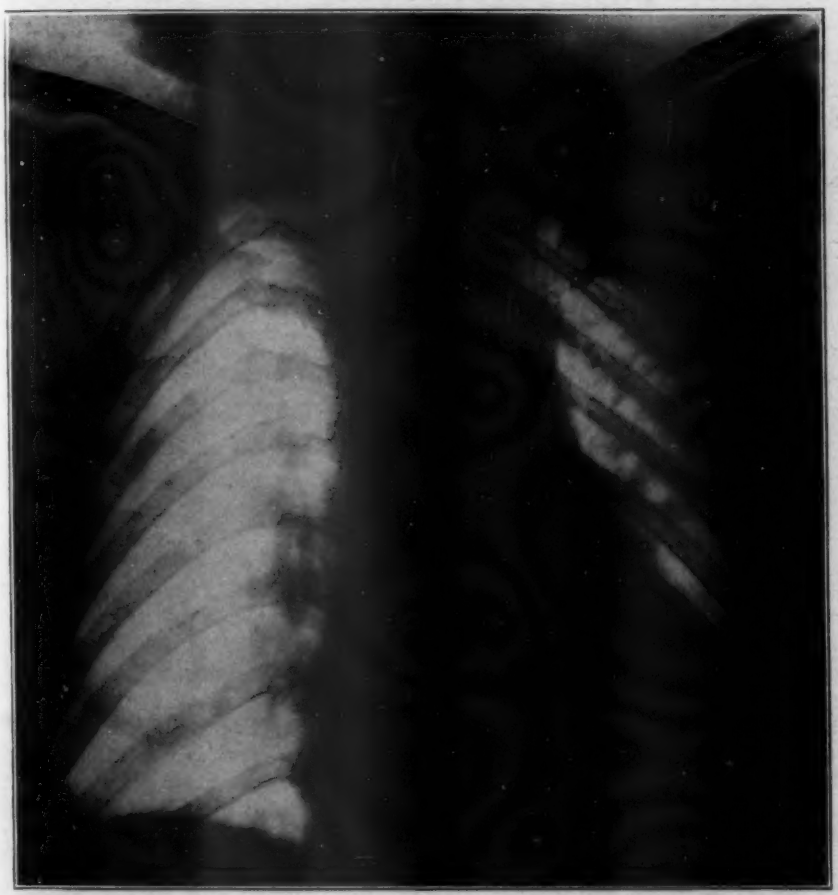

Fig. 7.—Partial collapse of the left lung following paralysis of the intercostal nerves from a high transverse myelitis.

During the period in which she was under observation, she was subject to repeated spells of dyspnea and was embarrassed by an unproductive cough. The physical examination of the chest showed diminution of the breath sounds and scattered râles throughout the left lung, varying in location from day to day. A roentgenogram (Fig. 7) showed diminished radiance of the left lung field, with displacement of the heart and mediastinal contents to that side.

The left intercostal spaces were narrowed, and the diaphragm was a little high on that side. There was no evidence of consolidation. The right lung appeared normal. These findings were considered by Dr. Holmes as attributable to incomplete aeration or partial collapse of the left lung.

COLLAPSE ASSCCIATED WITH MINOR EMBOLUS AND PLEURITIS

There is no pathologic basis for assuming that a minor pulmonary embolus could, in itself, produce immediate deflation of the lung, and experimental studies in this field (Karsner and Ash [38]) fail to suggest such a happening. The case reported below shows cardiac and mediastinal displacement appearing subsequent to a typical pulmonary infarction or minor embolus. This, we believe, was due to the development of extensive atelectasis of the right lung. That this is an unusual complication is shown by the fact that it has not been observed in a number of other cases of minor pulmonary embolism in this hospital, nor is it mentioned by writers such as Wharton and Pierson,[39] who have carried out careful clinical studies of this condition. It is thought that the development of the pulmonary atelectasis, in this case, was due to the splinting of the chest and diaphragm caused by the prolonged and extremely painful pleuritis which characterized the infarction. The collapse was also favored by adhesive strapping for the relief of pain, morphinization, and an irrational condition of the patient with maintenance of a position preventing the expansion of the right lung.

CASE 8.—W. W., a man, aged 63, a machinist, entered the hospital with a large tumor of the left thigh, which proved to be a dermoid cyst at operation. The ether anesthesia was uneventful; the cyst was marsupialized, and convalescence was normal until the fifteenth day. At this time, there was a sudden onset of pain in the right side of the chest with the sharp rise in temperature, pulse and respirations which commonly attends minor pulmonary embolism. A loud crunching friction rub soon appeared at the right base, where there was also some dulness to percussion. There was no cough or sputum until three days later, when the patient raised a small amount of blood-streaked sputum. At this time the area of dulness was well defined, with increase of tactile and vocal fremitus and a few crackling râles, but no bronchial breath sounds. The pleural pain continued with great severity, and, for relief, the right side of the chest was strapped with adhesive plaster. Morphin was administered regularly.

On the fourth day following the infarction, it was noted that the apex impulse of the heart was 2 cm. inside the nipple line, and a roentgenogram, taken the following day, showed apparent displacement of the heart to the right, with dulness in the lower half of the right chest. This displacement of the heart and mediastinum to the right was confirmed by a second roentgenogram two days later, and an additional note of narrowing of the intercostal spaces on that side was made. A roentgenogram of the chest taken before the operation had shown a normal position of the heart and normal lung fields at that time. The patient rapidly grew worse, becoming irrational and then

38. Karsner, H. T., and Ash, J. E.: J. M. Res. **22**:205, 1912.

39. Wharton, L. R., and Pierson, J. W.: Minor Forms of Pulmonary Embolism After Abdominal Operations, J. A. M. A. **79**:1904 (Dec. 2) 1922.

comatose; the temperature became higher, and an acute synovitis of the right knee confirmed the presence of a terminal septicemia. No necropsy was permitted.

NECROPSY FINDINGS IN PULMONARY COLLAPSE

The favorable prognosis of the usual case of massive collapse has caused a paucity of necropsy material available for analysis, so although the collapse in the following case cannot be said to be a postoperative complication, the interesting anatomic findings warrant its presentation.

CASE 9.—K. C., a woman, aged 65, a graduate nurse, presented herself with a large tumor of the left hypochondrium associated with ascites. A

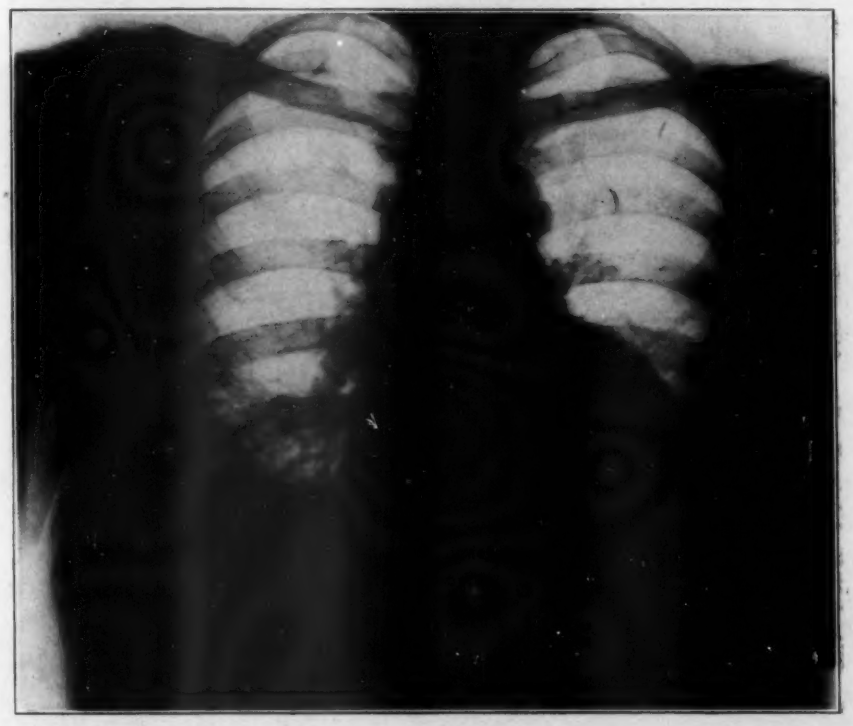

Fig. 8.—Preoperative shadow at the left base that may represent a collapsed lower lobe in addition to some cardiac displacement.

preoperative roentgen-ray examination (Fig. 8) showed a high fixed diaphragm on the left side with what was thought to be an upward displacement of the heart. In view of the later findings, it is possible that the density at the left base may be due, at least in part, to a collapsed lower lobe. An exploratory laparotomy, under ether anesthesia, showed the tumor to be hopelessly inoperable, and a small specimen established the diagnosis of myxochondrosarcoma. During her convalescence, she was given several roentgen-ray treatments but steadily grew weaker, and on the twenty-sixth day, after a rather sudden onset of abdominal distention, accompanied by dyspnea and cyanosis, the patient died.

Necropsy was performed four hours after death, and confirmed the operative findings of a huge tumor mass occupying the left upper quadrant and pushing the stomach over to the right costal border. The dome of the diaphragm was opposite the fourth rib on the left, and the third rib on the right. It was apparent that respiratory movement of the left half of the diaphragm would have been markedly limited by the mass and fixation of the underlying tumor. There was 500 c.c. of pale fluid in the left pleural cavity.

The lower lobe of the left lung was completely devoid of air, being dark red, noncrepitant, and of the consistency of a fragment of soft muscular tissue. Portions sank to the bottom when placed in water. There was no gross evidence of bronchial obstruction, and the amount of secretion in the bronchial tree was not abnormal. Portions of the lung could readily be inflated by blowing air into a bronchus, the alveoli distending in a normal manner, but showing a tendency to return to the collapsed condition when the pressure was released. The lower border of the left upper lobe showed a similar condition, as did also the posterior medial border of the right lower lobe. In the left upper lobe, there was also an area of atelectasis definitely limited to one lobule, appearing on the surface of the lung as an irregular, depressed area of bluish discoloration. Microscopic examination of sections from these areas confirmed the atelectasis, and showed no evidence of inflammation or exudation.

The distribution of atelectasis is well shown by a roentgenogram of the specimen (Fig. 9) in which the collapsed portions appear as regions of increased and even density in contrast to the mottling of the normally aerated regions. Unfortunately, the contrast both in volume and density is lessened by the partial collapse of the rest of the lung naturally attendant on the removal of the organs from the thorax without ligation of the trachea.

It is, of course, not maintained that the collapse of the left lower lobe was due to the operation, a more reasonable explanation being that the atelectasis was present when the patient entered the hospital, but was not recognized by either physical or roentgen-ray examination. The collapse, in this case, is associated with the high fixed position of the diaphragm and the small amount of fluid in the pleural cavity, but there was very little, if any, actual encroachment on the volume of the pleural cavity in its expiratory phase. The collapse of the isolated lobule indicates an added factor of bronchial obstruction, in this case probably merely the accumulation of normal bronchial moisture.

SIGNS AND SYMPTOMS

Observations on the foregoing cases have added little to the symptomatology as described by previous writers. It is seen that the attack may be sudden or insidious in onset; alarming or extremely mild in its course; almost universally favorable in its prognosis, and without notable sequelae as far as present records indicate. The presenting symptoms are dyspnea, at times attended with cyanosis; dull pain beneath the xiphoid; elevation of temperature, pulse and respiratory rate, and a cough with the production of purulent sputum.

It is agreed that the one most important finding on physical examination is displacement of the heart and mediastinum toward the collapsed lung. Without this sign as a cornerstone, the diagnosis is precarious and must be considered open to question. In our hands, it has frequently been found difficult to determine with any degree of precision the exact position of the heart by the ordinary methods of physical examination

Fig. 9.—Specimen removed at necropsy; complete atelectasis of the left lower lobe; areas of deflation in other portions of the lung. The arrow indicates a patch of atelectasis confined to one lobule; the dark markings are tracheal nodes and normal cartilaginous rings.

in postoperative patients. These individuals are sick, breathe rapidly, and present varying degrees of abdominal or gastric distention. It has been our custom, therefore, to rely on roentgenograms taken with a portable apparatus for confirmation of the diagnosis.

In patients with pliant chest walls and thin overlying musculature, the unilateral immobility with retraction and narrowing of the inter-

spaces is a striking feature. In broad-chested, muscular patients, this finding is less pronounced.

A glance at the varied roentgenograms in even this small series of cases gives sufficient explanation for the variation in the auscultatory signs encountered not only in different cases but also in the same individual at different stages in the course of the disease. Most of the cases examined, however, may, for purposes of description, be divided into three groups, the signs of each of which are in accord with the underlying pathologic condition, as indicated by a corresponding roentgenogram. A single case may present two or possibly all three pictures on successive examinations.

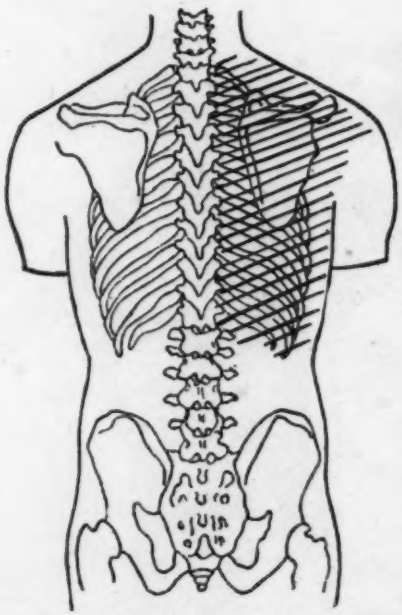

Fig. 10.—Signs in complete collapse of the right lung, possibly with superimposed "drowning."

1. *Complete Collapse, Possibly With "Drowned Lung."*—Only one instance of this extreme type has been under our observation (Case 3), but Leopold [30] reports four cases of a similar nature. The physical signs (Fig. 10) are compatible with the extreme roentgenographic density, and indicate a complete lack of aeration of the affected side. It is probable that the distant bronchial breathing was transmitted from the large bronchi of the other lung, accentuated by the mediastinal displacement. During the expansion of the lung, in this case, numerous moist râles appeared.

2. *Complete Collapse of the Lower Lobe With Partial Collapse of the Remainder of the Lung.*—A number of cases, in this series, when first observed presented findings as charted in Figure 11, which are associated with a roentgenographic picture similar to Figure 6. The high, fixed diaphragm with complete collapse of the lower lobe accounts for the signs of fluid at the base, while the relative resonance and louder, although still much diminished, breath sounds indicate the presence of air in the upper portion of the lung. The patch of intense bronchial breathing with increased tactile and vocal fremitus at the angle of the scapula is an almost constant finding in this stage, and is subject to one

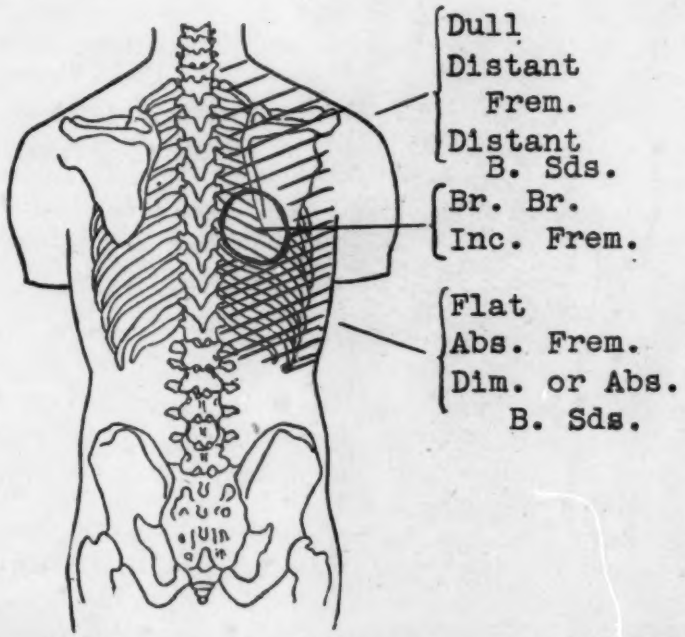

Fig. 11.—Signs in complete collapse of the lower lobe and partial collapse of the remainder.

of two interpretations. These signs, classically those of consolidation, may be attributed to a patch of bronchopneumonia at the hilum which, in turn, may be the cause of the atelectasis, according to the suggestion of Lord. An alternative explanation, and to me the more probable, is that the mediastinal displacement brings the right primary bronchus or even the tracheal bifurcation beneath this area of the chest wall, and the auscultatory signs are those familiarly heard over the spine in normal chests. In support of the latter interpretation may be mentioned the absence of râles in association with the other signs, and in one case a definitely hyperresonant note, which was obtained by percussion.

3. *Collapse of the Lower Lobe.*—The signs indicating collapse of the lower lobe when the remainder of the lung is fully expanded are definite, but may be readily overlooked. The signs at the base (Fig. 12) are those of fluid, as in the preceding stage, and are attributable to the high fixed diaphragm in addition to the atelectatic lobe. The striking feature of the rest of the affected side is the marked diminution of the intensity of the breath sounds. This finding is considered by Rose Bradford to be the most important auscultatory sign of massive collapse, and is due to complete cessation or a great diminution of the movement of air in and out of the affected lung. The term "silent area" might well be

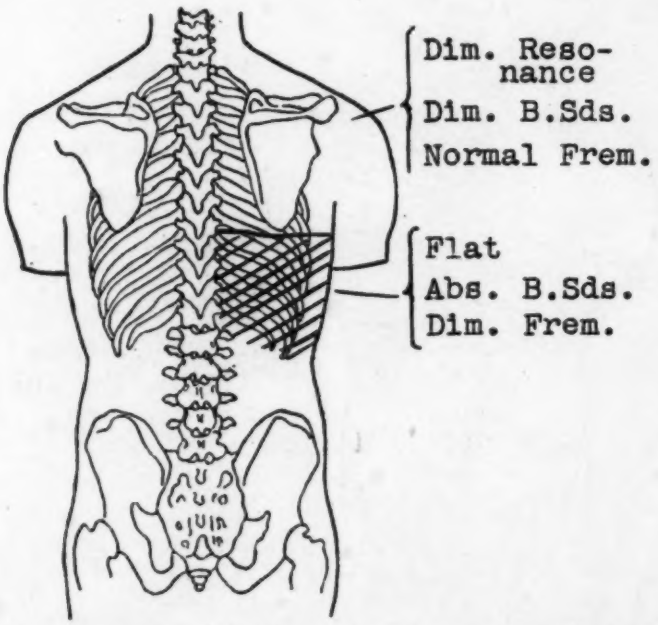

Fig. 12.—Signs in complete collapse of the lower lobe with air-containing but "silent" upper and middle lobes.

borrowed from the neurologists in description of this phenomenon. That this remaining lung tissue contains air is evidenced by the normal transmission of tactile and vocal fremitus and only slight impairment of resonance, the latter being attributable to the encroachment of the mediastinum and the diaphragm on this pleural cavity.

ETIOLOGY

A study of the foregoing cases and a review of the literature show that two conditions are almost universally present in clinical states in which pulmonary collapse is of common occurrence—weakened respiratory force and bronchial obstruction. These two factors play rôles of

varying importance in different cases: thus, extreme debility plus even normal bronchial moisture may result in areas of atelectasis, and, conversely, a foreign body may cause collapse with normal respiratory power. In most instances, however, and probably in all postoperative cases, the collapse results from the combined action of the two factors. Before considering the mechanism of their combined action, it will be helpful to consider each factor singly.

DECREASED RESPIRATORY FORCE

An abnormally low respiratory force may be encountered in a variety of clinical states, and may result from a number of mechanical factors. Atelectasis was first described in new-born infants, and is known to complicate respiratory or other diseases of infancy with far greater frequency than it is encountered in the adult. The weak respiratory force of an infant is dependent on two factors—the pliant chest wall and the lack of a notable negative intrapleural tension. The latter is to be explained by the well known fact that the lungs of the infant completely fill the thorax when almost unexpanded, negative pressure only becoming established during growth, when the size of the thorax seems to increase out of proportion to that of the lungs.

The weakened muscular force attendant on a long, wasting illness in the adult may predispose to the development of atelectasis. This takes place as a commonly recognized complication of typhoid fever, and internists guard against its occurrence by frequently changing the position of the patient. Atelectasis of the left lower lobe was found at necropsy in a case of myasthenia gravis, reported by Buzzard,[40] the patient dying in an attack of dyspnea. Here, again, muscular weakness would seem to have been the predominant factor. Paralysis of the intercostal muscles as a result of a cord injury was shown in Case 5 to be followed by atelectasis sufficient to produce mediastinal displacement toward the affected side. This condition is perfectly comparable to the collapse following diphtheric paralysis of the diaphragm described by Pasteur, and shows that it is the diminution of respiratory force which is the important factor, rather than the loss of any function peculiar to the diaphragm.

Restriction of the movements of the respiratory muscles to a degree which markedly decreases the force of respiration may occur as the result of conditions other than paralysis. The entire problem of the arrest of action of the diaphragm through reflex inhibition is rather obscure, particularly were we to consider the phenomenon limited to one-half the organ, as does Pasteur. It is well known that skeletal muscle commonly assumes a state of increased tonus or spasm in the

40. Buzzard, E. F.: Brain **28**:458, 1905.

presence of adjacent inflammation. Such a condition, in the diaphragm, would be manifested by fixation of that organ in a low position, rather than fixation in the high position commonly found associated with a collapsed lung. Briscoe [20] carried out extensive experiments on rabbits in an attempt to influence the respiratory excursion of the diaphragm, but could not produce a reflex arrest of one-half that organ. The greatest difference in the excursion between the two halves was obtained by merely placing the animal on one side, but the results were at variance in different animals.

The involuntary limitation of respiratory movements, not only of the diaphragm but also of all respiratory muscles, is commonly seen in conditions in which the act of respiration is attended by pain. This may best be illustrated by the reluctance to cough or breathe deeply which is shown by patients who have recently been subjected to a laparotomy. We are now carrying on observations which show that the vital capacity of patients with a recent abdominal incision is, at times, reduced to one-third its preoperative amount. Severe pleuritic pain has the same effect, and, in Case 6, was probably the major factor in the production of atelectasis.

The restriction of diaphragmatic excursion may be due to purely mechanical factors, such as the extreme abdominal distention associated with peritonitis, or, more rarely, to a condition such as the large abdominal tumor described in Case 7. Mechanical factors limiting respiratory excursion may also be extraneous, for it is certain that a tight abdominal swathe applied in a manner that restricts the movements of the costal border, may markedly impair pulmonary ventilation; and, as mentioned above, prolonged maintenance of the dorsal decubitus, particularly by enfeebled patients, predisposes to the development of atelectasis.

BRONCHIAL OBSTRUCTION

It was so clearly shown by Elliott and Dingley [18] that bronchial obstruction is an essential factor in the production of massive collapse that their argument is worth quotation in full.

> An active deflating force, such as pressure from outside the lungs or the elasticity of the alveolar walls, carries with it inevitably the deduction that the pressure about the lung must be higher on the affected than on the normal side. This is self-evident for the former, and equally certain for the latter. The elastic tissue of the alveolar wall is expanded by the pull of the negative intrathoracic pressure, and unless endowed with an active power like that of muscle [41] it cannot squeeze the air out of the lung until it is freed from this

41. The contraction of muscular elements of the lung by reflex stimulation, excepting the well known contraction of bronchial musculature, is purely hypothetic and contrary to histologic studies which have universally failed to

Footnote 41 continued on next page.

external distending pull. Consequently, if either external muscular force or internal elasticity is to effect the collapse, the intrapleural pressure must be raised from negative toward zero; and in that case the heart would be sucked away from the collapsed side into the contralateral area of greater negative pressure. Actually the displacement is in the opposite direction.

In the absence of a foreign body, bronchial obstruction may be produced by accumulated normal secretions, inflammatory exudate, or spasm of the bronchial muscles. As Sewall [9] suggests, it is not unlikely that many areas of the pulmonary tissue remain collapsed during the expansion of normal respiration, just as a great proportion of the volume of the capillary network is devoid of blood under normal conditions. This physiologic atelectasis is most marked in the regions of the lungs which are least subjected to the muscular forces producing inspiratory expansion; thus, in the average individual in the upright posture, it is a common fluoroscopic finding to note a diminished radiability of the apexes, which only "light up" on forced inspiration. Similarly, in patients confined to bed and kept in the dorsal decubitus position, areas of atelectasis are commonly found in the dependent areas of the lungs. The possibility of even the normal moisture and secretion of the mucous membrane playing a rôle in the production of this form of atelectasis will be apparent if it is remembered that the terminal respiratory bronchioles are less than 0.5 mm. in diameter (Lewis and Stöhr).

Although Pasteur, in his definition of massive collapse, states that it must occur in the absence of any signs of obstruction of the airway, he says also that a viscid expectoration is an early symptom in most cases, and is probably due to mucus pressed out of the collapsing lobe. This sputum, usually greenish mucoid or mucopurulent, he says makes its appearance within an hour or two of the onset of the attack, too soon to be the product of inflammatory changes in the lung resulting from the collapse. Rose Bradford, on the other hand, considers that the limitation of a purulent bronchitis to the collapsed lobe, as demonstrated at necropsy, is evidence of the inflammation being a result rather than a cause of the collapse.

The early production of a purulent sputum in a moderate amount has been an almost constant feature of the postoperative massive collapse cases reported in the literature, and it has been present in all the cases which have been under our observation. In several of these cases, there

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Footnote 41 concluded.
confirm the existence of any such muscular fibers. The interesting work of Carlson and Luckhardt (Am. J. Physiol. **54**:55, 122 [Nov.], 261 [Dec.] 1920) on the contraction of the lungs in amphibians and reptiles as a result of vagal stimulation, cannot be applied to the lungs of mammals, for, as these authors state, so far as we know the mammalian lung has no counterpart to the lung wall musculature of the frog.

has been a history of preoperative respiratory infection with cough and sputum; two patients had previously postponed their operation because of a cold. The fact that the right lower lobe is the one affected most markedly in the majority of cases may be attributable to the anatomic structure of the bronchial tree, which favors the gravitation of exudate or secretion to this lobe.

Besides the actual presence of inflammatory exudate in the bronchi acting as a cause of bronchial obstruction, a possibility suggested by Lord is that a localized inflammatory edema of a bronchus may be caused by proximity to an area of bronchopneumonia. Thus, a patch of bronchopneumonia near the hilum might readily cause partial or even complete obstruction to a large bronchus.

It is well known in physiologic laboratories that vagal stimulation will produce bronchoconstriction, and Dixon and Brodie [15] record extensive studies on the different phases of this phenomenon. Reflex bronchiolar constriction was produced by exciting the mucous membrane of the nose, the central end of one vagus, the central end of the accellerators, and the central end of the anterior crural nerve. Jackson [42] found that the response of the bronchi to the action of certain drugs is much more certain and reliable than is the response to electrical stimulation of the vagi. He also reports that the inhalation of ether or chloroform for anesthetic purposes abolishes the effect of the vagus on the bronchioles, and attributes this to a paralysis of the nerve endings by direct absorption of these drugs through the mucous membrane. This last observation is of importance for both clinical and experimental studies in this field.

Clinical evidence regarding the action of the bronchial musculature is by no means abundant, although the extensive bronchoscopic observations, notably of Chevalier Jackson, have abolished the concept of the bronchial tree as a system of rigid walled tubes. Bullowa and Gottlieb [43] have shown, by roentgenologic studies, that a spastic contraction of the bronchi serves to limit the expansibility of the lung as well as to diminish the caliber of the bronchi. Future observations must determine whether reflex bronchoconstriction plays a part in the production of pulmonary collapse, and it is particularly suggested by the type of case occurring with war wounds when evidence of other mechanism of bronchial obstruction is lacking. Case 3, in our series, gave a definite history of hay-fever and asthmatic attacks, which, in view of some recent theories regarding the etiology of asthma, might be interpreted as indicating a hyperirritability of the parasympathetic system (vagotonia), making it more susceptible to reflex stimulation of whatsoever origin.

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42. Jackson, D. E.: J. Pharmacol. & Exper. Therap. **4**:59, 1912-1913.
43. Bullowa, J. G. M., and Gottlieb, C.: Am. J. M. Sc. **160**:98 (July) 1920

THE PRODUCTION OF ATELECTASIS

It is a fact well known experimentally and clinically that complete occlusion of a bronchus will be followed by collapse of the corresponding area of lung. With complete blocking of the lumen, this atelectasis must result from the absorption of the air by the blood. In special cases with obstruction of a bronchus by a movable foreign body, it cannot be denied that the lung may become emptied by a ball-valve action of the foreign body.

It has been demonstrated by Jackson, Spencer and Manges [44] that partial occlusion of a bronchus by a foreign body may result in a distention of the lung which appears to result from an enlargement of the bronchial lumen during inspiration allowing the passage of air, which is prevented from escaping during expiration by a diminution of the bronchial lumen. A simple ball-valve action of the obstructing body could not produce distention in a series of tubes of diminishing caliber, such as the bronchial tree. This phenomenon of inflation is also noted by Wessler and Jaches [45] who reproduce a roentgenogram showing in the same patient collapse of one lobe from complete obstruction, and distention of another by partial occlusion of the lumen. In their case, both the partial and the complete obstruction were due to pressure of enlarged bronchial nodes, so any ball-valve action is excluded. Further, it is a familiar clinical fact that the partial obstruction caused by the bronchoconstriction in asthma results in hyperinflation of the lungs; and, here again, unless mucus is considered to be the real cause of the obstruction, ball-valve action cannot be a factor.

The clinical evidence seems to show, therefore, that while complete bronchial occlusion results in atelectasis, partial bronchial occlusion may produce hyperinflation. The next consideration is whether partial occlusion can cause atelectasis and, if so, what conditions determine the production of inflation, on the one hand, and deflation on the other.

The work of Dixon and Brodie, although it centers about the action of the bronchial musculature, throws considerable light on this problem of what may determine whether bronchial obstruction will cause deflation or inflation of the lung. Their work was done with artificial respiration, and certain differences between the pressures in artificial and normal respiration must be considered.

Leaving aside for a moment the part played by the varying resistance of the air passages to the flow of air, we may say that the volume of air taken into the lungs at a given inspiration is dependent on two factors:

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44. Jackson, C.; Spencer, W. H., and Manges, W. F.: Am. J. Roentgenol. 7:277 (June) 1920.

45. Wessler, H., and Jaches, L.: Clinical Roentgenology of Diseases of the Chest, Troy, N. Y., 1923.

the difference in pressure between the pharynx and the alveoli, and the time allowed for the air to enter. In artificial respiration the first factor would be the difference between a positive pressure in the pharynx and atmospheric pressure in the alveoli; while, in normal respiration, the pressure potential is determined by the difference between atmospheric pressure in the pharynx and a negative pressure in the alveoli. So, while the actual pressure values are different in the two types of respiration, the potential pressure, which is really the first factor in the equation that determines the volume of air entering the lung, is presumably the same for a given degree of inflation, whether brought about by natural or artificial respiration.

Dixon and Brodie [15] were able, by rapid forceful respirations, allowing a short time for expiration, to produce distention by bronchoconstriction. Thus, with an increased potential and a shortened expiratory phase, the added opposition of bronchial obstruction produced distention. Again, with less forceful respiration and an interval sufficiently long to allow full expiration, constriction of the bronchioles resulted in collapse. With a potential below normal values, air was not carried beyond the obstruction as rapidly as the gaseous contents of the lobe were being absorbed by the blood stream, and collapse resulted.

These conditions would seem to be entirely comparable to those found in clinical states. A low negative pressure, such as is found normally, in infants, or as the result of diminished respiratory excursion, in the adult, may be considered as establishing a low potential. It is probable that, under such conditions, large areas of the lung are maintained in an expiratory phase containing only residual air, and that air only enters these "silent" areas at the rate that their contents are being absorbed by the blood. The location of these areas is dependent on the portion of the respiratory mechanism affected; thus, the lower lobes would be involved in conditions affecting the integrity of the diaphragm. As Hoover [46] states, "not only may pulmonary ventilation be very unequally distributed in the respiratory units through disease of the intrinsic pulmonary tissues and air passages, but ventilation may also be greatly impaired by disease of the motor organs, namely, the intercostal muscles, diaphragm and scaleni."

Further, in postoperative patients, we commonly see a shortened inspiratory phase followed by a prolonged expiration—the second condition present in the experiments of Dixon and Brodie, namely, the existence of an interval sufficiency long to allow full expiration.

The stage is thus set for the action of bronchial obstruction, either complete or partial, which may occur in one of the manners discussed above. The obstruction permits further deflation by the absorption of the residual air by the blood, thereby bringing about complete atelectasis.

46. Hoover, C. F.: Oxford Loose-Leaf Medicine **2**:29.

THE RELATION OF ATELECTASIS TO PNEUMONIA

The possible rôle of pneumonia in the production of atelectasis has already been discussed, and now it may well be asked whether atelectasis predisposes to pneumonia. Elwyn [25] and, more recently, Lee [31] suggest that an area of atelectasis is a *locus minoris resistentiae* for the development of bronchopneumonia. As these small areas probably exist in varying number after every operation, these authors believe them to be of great importance in the causation of postoperative pneumonia. It would seem, however, that both clinical and experimental proof for this assumption is lacking, no matter how attractive the hypothesis may seem.

In a review of the literature, which contains over 150 cases of nontuberculous pulmonary suppuration treated by artificial pneumothorax, only one instance was found in which the process was stirred up to immediate extension by the induced collapse. The entire rationale of the pneumothorax therapy of tuberculosis is that pulmonary collapse favors a limitation of the infectious process and promotes healing of the diseased lung. Packard [47] reports the advent of gangrene of the lung following partial artificial collapse in an ordinary active case of tuberculosis, but attributes the occurrence to necrotic areas due to obliterative endocarditis. In a review of the literature, he was not able to find a single similar case.

A case of bronchopneumonia which was relieved as if by magic following an artificial pneumothorax is recorded by Bernard,[48] and doubtlessly other similar cases appear in the literature. Experimentally, Corper, Simon and Rensch [49] have found that unilateral artificial pneumothorax or compression of one of the lungs of the rabbit by means of fluid, artificial hydrothorax, has no visible macroscopic influence on the number or type of the tuberculous lesions resulting from the intravenous injection of tubercle bacilli. So in the absence of direct positive evidence, it must be considered that there is little ground for the belief that atelectasis in itself favors the development of pneumonitis. The possibility that the same factors which produce atelectasis may also favor the development of pulmonary infection deserves separate consideration.

In this connection, it is worth while considering the relationship between atelectasis and minor pulmonary embolism. As stated above, we see no mechanism whereby an embolus could produce immediate pulmonary collapse,[50] but it is possible that a preexisting area of atelec-

47. Packard, E. N., Jr.: Am. J. M. Sc. **151**:887 (June) 1916.

48. Bernard, L.: Bull. et mém. Soc. méd. d. hôp. de Paris **47**:1638, 1923.

49. Corper, H. J.; Simon, S., and Rensch, O. B.: Am. Rev. Tuberc. **4**:592 (Oct.) 1920.

50. Schloepfer (Arch. Surg. **9**:25 [July] 1924) reports a very gradual reduction in size of the lung after ligation of a branch of the pulmonary artery. Displacement of the mediastinum was noticeable only at the end of a week.

tasis might alter the effect of an embolus which chanced to lodge within its borders. This is suggested by the experiments of Karner and Ash,[38] which show that embolism in such an area would lead to the production of true infarction with hemorrhage and necrosis. These authors studied the pathologic course of bland emboli, and found that true infarction, if one considers hemorrhage and necrosis as the criteria, resulted only when the lobe was congested by ligation of the pulmonary vein, or collapsed by an artificial pleural effusion. In areas of normal pulmonary tissue, embolism was followed by temporary congestion and, later, fibrosis of the alveolar walls.

SUMMARY

1. Postoperative massive collapse of the lung is believed to be merely a special manifestation of pulmonary atelectasis, a condition which is commonly found in a number of other clinical states.

2. Of six typical cases of postoperative atelectasis, two followed operations under local anesthesia.

3. A case of atelectasis was associated with paralysis of the intercostal muscles; two others were associated with minor pulmonary embolus and subdiaphragmatic tumor, respectively.

4. The most important diagnostic sign of postoperative massive atelectasis is displacement of the heart and mediastinum toward the affected side. The auscultatory signs vary with the extent and nature of the pathologic process, and are correlated with the roentgen-ray picture.

5. It is believed that pulmonary atelectasis results from the combined action of weakened respiratory force and bronchial obstruction. These two factors may be caused by different agencies, and play rôles of varying importance in different cases.

6. It is doubtful whether atelectasis, in itself, predisposes to pneumonia. While pulmonary embolism does not cause atelectasis, except as an accompaniment of the subsequent fibrosis, it is possible that an area of pulmonary collapse may alter the pathologic course of an embolus which chances to lodge within its borders.

TUBERCULOSIS OF MECKEL'S DIVERTICULUM ASSOCIATED WITH TUBERCULOUS APPENDIX

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It has long been recognized that Meckel's diverticulum has been the exciting factor in a wide range of abdominal pathologic conditions. Priority must be given to Littre,[1] who, in 1770, reported a case in which the diverticulum was the sole occupant of a hernial sac, and thus gave his name to this type of hernia. Ruysh [2] called attention to it, in 1701, in his "Thesaurus Anatomicus," and gave it the name of diverticulum and presented an illustration. Johann Friederich Meckel [3] was the first to describe in full this vestigial organ, and advanced the theory that it originated in the remains of the omphalomesenteric duct. Indeed, Fitz,[4] in 1884, said: "We owe to this author (Meckel) not only the universal acceptance of his theory of origin of the pouch in question, but also are indebted to him for calling conspicuous attention to its importance in the causation of serious disease." Opinions vary as to the frequency with which it is involved in pathologic processes. Foss [5] states that "many have never had occasion to remove it, so infrequently it is present and so rarely involved in disease." Balfour,[6] however, reporting on 10,000 consecutive laparotomies at the Mayo Clinic, states that, of the fifteen times the organ was found, it was involved in five, or 33 per cent.; but, as it is exceedingly apt to be overlooked unless definitely searched for, this percentage of involvement is probably high. Turner,[7] in 10,360 necropsies, found it present in eighty-one cases, and pathologic changes were demonstrable in 25 per cent. Porter,[8] in 1905, was able to compile 184 cases of abdominal crises due to diverticulum, and his monograph is a most valuable contribution to the literature on the subject.

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1. Littre: Mém. Acad. de sc., 1700, p. 300.
2. Ruysh: Thesaurus Anatomicus **7**:283, 1701.
3. Meckel, J. F.: Reil u. Autenrieths' Arch. f. d. Path. **9**:428, 1809; Beitr. z. Vergleichenden Anatomie **93**, 1808; Handbuch des Pathologischen. Anatomie, 1812; Tabulae Anatomico Pathological **3**:5, 1882.
4. Fitz, Reginald: Edinburgh M. J. **23**:120, 1908.
5. Foss, H. L.: Meckel's Diverticulum and Intestinal Obstruction, J. A. M. A. **81**:99 (July 14) 1923.
6. Balfour: J. Minnesota Med. **21**:110-112, 1911.
7. Turner: Guy's Hosp. Rep. **60**:279, 1906.
8. Porter, M. F.: Abdominal Crises Caused by Meckel's Diverticulum, J. A. M. A. **45**:883 (Sept. 23) 1905.

While reports of the incidence of Meckel's diverticulum vary widely, the consensus of opinion places it at about 2 per cent. of all persons. According to Hilgenreiner,[9] the relative frequency is 1.54 per cent., while Doepfner,[10] reporting on 1,822 necropsies at the Zurich Pathologic Anatomical Institute, found the diverticulum in fourteen, or in nearly 0.77 per cent. He states that, in middle and northwestern Europe, practically 1.53 per cent. of persons are carriers of a diverticulum. As regards sex, it occurs about twice as frequently in the male as in the female.

TYPES OF INVOLVEMENT OF DIVERTICULUM

The diverticulum may be involved in the following pathologic conditions:

1. It may form an umbilical fecal fistula due to the persistence of the omphalomesenteric duct in its entirety.

2. It may form a prominent, reddened, omphalo-adenoma if only the umbilical portion remains while the diverticulum itself becomes obliterated.

3. It may form a cyst by closure of the duct at either extremity. True cyst is exceptionally rare, McGlannan's[11] case being the only example found after careful search of the literature.

4. When the diverticulum has no parietal attachment but lies free in the abdominal cavity, acute inflammatory changes may take place due to torsion, compression, a foreign body or fecal concretions.

5. Ulceration of the diverticulum with or without perforation may occur.

6. Bursting as a result of trauma may occur.

7. Intestinal obstruction may be the result of intussusception of the diverticulum into the ileum. Strangulation due to the diverticulum acting as a band or volvulus of the loop from which the diverticulum arises and strangulation in a hernial sac may occur. Hilgenreiner compiled 185 cases in which intestinal obstruction was due to the diverticulum.

8. Neoplasms, including sarcoma, carcinoma, cylindroma, endothelioma, lipoma and adenoma, have been reported.

9. Typhoid perforation.

10. Hypomyces infection (Denecke).

11. Tuberculosis.

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9. Hilgenreiner: Beitr. z. klin. Chir. **40**:702, 1902; **40**:99, 1903.

10. Doepfner: Deutsch. Ztschr. f. Chir. **109**:396, 1911.

11. McGlannan, Alexius: Intestinal Obstruction, J. A. M. A. **65**:673 (Aug. 21) 1915.

It is not our purpose to take up in detail a discussion of the various abnormalities of Meckel's diverticulum but to limit ourselves more particularly to a consideration of tuberculosis of that organ.

TYPES OF INTESTINAL TUBERCULOSIS

Intestinal tuberculosis in general has been classified, according to the French school, into three types:

1. Ulcerative, which consists of a tuberculous enteritis. This is common, and is often a primary lesion in children. It occurs in adults as a secondary lesion in cases of advanced pulmonary tuberculosis. Weigert [12] asserts that it is present in 90 per cent. of cases of advanced pulmonary tuberculosis. This type is not generally considered a suitable field for surgery, although Archibald [13] has operated on about sixty patients—with benefit in some instances—by resection or bilateral exclusion or sidetracking procedures.

2. Cicatricial or stenosing, which results from contracture of the completely healed ulcer, which produces a narrow fibrous stricture giving the appearance of a ligature tied about the intestine. Its site is usually in the small intestine, and it may be multiple. When present in the large intestine, it may make a shelflike projection into the lumen, but never causes real obstruction.

3. Enteroperitoneal, which selects the ileocecal region, and which combines ulceration with hyperplasia of the intestinal wall; also, it involves the adjacent peritoneum, mesentery and lymph nodes. It may form a tumor by matting together of loops of bowel, and fecal abscess resulting from perforation of an ulcer is common. Occasionally, a spontaneous entero-enterostomy takes place between the adjacent loops of intestine. Judging from descriptions of reported cases, it is in this group that most of the examples of tuberculosis of Meckel's diverticulum belong.

PATHOGENESIS

There are two theories frequently advanced as to the mode of infection of tuberculosis of the bowel: (1) that the infection is blood borne and is due to the dislodgment of tubercle bacilli from some focus in lung or lymph node into the blood stream, which carries them into the terminal blood vessels in the intestinal tract (Archibald feels that this is the case in the majority of instances, although he does not advance any

12. Weigert: Jahrbuch für Kinderheilkunde **21**:147, 1884.

13. Archibald, E. W.: Surgical Treatment of Ulcerative Intestinal Tuberculosis as Occurring Chiefly in Pulmonary Tuberculosis, Canad. M. A. J. **10**:804 (Sept.) 1920.

evidence to support this belief); (2) that the swallowed tubercle bacilli gain entrance directly through the intestinal mucosa (this is the theory held by Weigert).

Archibald states:

> The early tubercle, to judge from sections, is usually in the submucosa, and frequently not in the lymphoid tissue of that layer. Occasionally it is in the subserosa, but very seldom if ever primarily in the muscle, which is a real barrier to the extension of the tubercle. Breaking down occurs usually towards the mucosa with the formation of an ulcer, though rarely its extension is in the other direction. . . . One can recognize it by a slight nodular thickening felt upon careful palpation, by a general patchy edema of the wall of the bowel, through which the wall seems to have lost its elasticity; thirdly, by the presence of a rosette of capillary congestion opposite the tubercle in the peritoneal coat; and, finally, by a patch of fibrinoplastic exudate forming a sort of veil or tag upon the peritoneum.

CASES FROM THE LITERATURE

The instances of tuberculosis of Meckel's diverticulum recorded in the literature are:

Case 1 (Italo Antonetti[14]).—A man, aged 20, who showed various manifestations of tuberculosis in infancy, gave a history of malaria, and had been troubled with periodic attacks of abdominal pain and associated constipation. He was suddenly seized with a chill and general malaise, which were followed by pain in the right lower quadrant, which radiated into the groin and right testis, finally localizing to McBurney's point. There appeared in succession meteorism, a mass in the ileocecal region and constipation. These symptoms subsided under medical treatment in about twelve days. A similar attack occurred three months later, at which time the patient was admitted to the hospital, with a temperature of 39 C., pulse 106, and violent pain in the right lower quadrant.

Examination showed slight distention, and, on palpation, considerable induration and resistance to pressure in the ileocecal region. The bowels were constipated. A delay of thirty hours was based on the belief that the condition was one of subsiding appendicitis; at the end of this time, symptoms of obstruction necessitated operation, which disclosed multiple adhesions between the omentum and parietal peritoneum, together with a mass composed of coils of intestine adherent to each other and to the omentum by old and recent adhesions. When these adhesions were freed, a long diverticulum was found adherent to the cecum and to the parietal peritoneum of the iliac fossa. On the diverticulum and the adjacent ileum were seen numerous miliary tubercles.

The diverticulum was resected, the appendix being left in place. The diverticulum was finger-like and measured 9 cm. in length; its caliber was twice that of the ileum. The ileum was narrowed at the site of the origin of the diverticulum. The patient recovered.

Case 2 (Dixon[15]).—A patient, dead of septic peritonitis, at necropsy, presented a Meckel's diverticulum which, on examination, showed perforations of two tuberculous ulcers which had allowed the escape of fecal contents.

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14. The previous history of this case, reported by Italo Antonetti (Riv. veneta d. sc. med., 1902-1903), closely parallels my case.

15. Dixon: Tr. Path. Soc. London, 1873, cited by Halstead, quoted by Porter

CASE 3 (Thompson[16]).—A woman, aged 65, with symptoms of threatened intestinal obstruction suffered recurrent attacks of colicky pain, which were referred to the right lower quadrant.

When the abdomen was opened, some attenuated adhesions were found between the cecum and anterior abdominal wall and between the different coils of lower ileum. The cecum, appendix and glands in the adjacent mesentery were normal. On pulling out the lower ileum, several coils were encountered, the loops of which were approximated by attenuated adhesions and, about 2 feet (60.9 cm.) from the lower end of the ileum, a diverticulum was found, about 1 inch (2.5 cm.) in length, springing from the bowel midway between the mesenteric attachment and the border opposite to this; in consistency, it felt remarkably solid, as if there were a growth in its wall. It was removed in the ordinary way with the appendix crusher and the gap closed by a purse-string suture. Recovery was made.

Sections of the diverticulum were made. Toward the free extremity, there were a number of rounded foci of giant celled tuberculosis scattered irregularly through the different coats of the bowel. Those in the deeper layers of the mucous coat appeared to be the oldest. There were several in the muscular coat, and at one point these had completely destroyed and replaced the circular muscularis. There were a number in the subperitoneal tissue, these having evidently disseminated by way of the lymphatics. The tuberculous foci showed a large number of typical giant cells and a considerable degree of central necrosis, while in their vicinity the vascularity was greatly increased and there was little fibrous tissue.

CASE 4 (Fitz[4]).—This author described a specimen, in the Warren Museum, which included a portion of inverted intestine, with a diverticulum. The latter was 2½ inches (6.2 cm.) in length and showed, on its inner surface (mucosa), three large tubercular ulcers.

CASE 5 (Concato).—Wirtz states that Concato refers to a case of tuberculosis of the diverticulum of Meckel in *Rivista Clinica di Bologna,* January, 1871; but further details are lacking as access could not be gained to the volume in question.

CASE 6 (Burkhardt[17]).—A woman, aged 24, was operated on for tuberculous peritonitis; the principal focus was found to be in the base of a Meckel's diverticulum, causing a stenosis of the intestine.

Resection of Meckel's diverticulum was done. The patient recovered, but died later of generalized tuberculosis.

CASE 7 (Wirtz[18]).—A woman, aged 20, who had been suffering from tuberculosis of the intestinal tract for some time, three months prior to admission,

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16. Thompson: Edinburgh M. J. **23**:120, 1908. While Thompson considered this case one of acquired diverticulum rather than of Meckel's diverticulum, its location, 2 feet (60.9 cm.) from the ileocecal valve, and its investment with the normal muscular tunics, together with the extreme rarity of reported diverticula of the acquired type in this region, would strongly suggest its origin from the remains of the vitteline duct, or that it was a true case of tuberculous Meckel's diverticulum.

17. Cited in paper before the Nurenberger Medical Society by Burkhardt: München. med. Wchnschr. **29**:1652, 1914.

18. Wirtz: Inaugural Dissertation, University of Bonn, Dec. 6, 1919. This case was observed at the Pathological Institute of the University of Bonn.

was suddenly taken ill with cough, hemoptysis pains in the chest and back, and also dyspnea, dizziness and night sweats. Later, she had suffered loss of appetite, great thirst and occasional vomiting.

Examination at time of entrance to the clinic, Dec. 23, 1918, showed a delicately built young woman with no edema or swelling of the glands. Examination of the lungs revealed typical physical signs of pulmonary tuberculosis, and examination of the sputum showed the presence of tubercle bacilli and blood. The abdomen was soft; there was no tenderness. The liver and spleen were not palpable. Roentgen-ray examination showed the entire right lung to be dense; to the left, there were small and medium sized shadows. The condition of the patient grew worse from month to month. May 6, she had a sudden severe intestinal hemorrhage, followed by death the next day.

Necropsy was done, May 8, 1919. There were about 300 c.c. of clear, yellowish fluid in the abdominal cavity. The small intestine, in the neighborhood of the cecum, was slightly dulled and covered with fibrin. The pericardium contained 150 c.c. of clear, yellowish fluid; the heart showed no changes. Both apexes of the lung were adherent; both upper lobes contained numerous tuberculous deposits and many ramified cavities. The spleen, kidneys, duodenum, stomach and liver showed no changes. In the small intestine, several tuberculous abscesses up to the size of a silver quarter were found.

The diverticulum, which was of the small intestine and about the size of the end phalanx of the thumb, was covered with small miliary nodules. The rest of the small intestine was glistening and smooth, except in the neighborhood of the cecum, where the above mentioned fibrinous covering was noted.

In the first portion of the large intestine and in the cecum starting at the valve, there was an irregularly defined abscess about the size of the palmar surface of the hand. The mesenteric glands were enlarged. There were a number of single, small abscesses in the colon.

CASE 8 (Ricketts[19]).—A man, aged 27, had symptoms of an acute partial intestinal obstruction. On laparotomy, a tuberculous peritonitis was revealed; the ileocecal valve was invaginated in a band extending from the ileum to the colon on the right side (Meckel's diverticulum?).

A laparotomy was performed with resection of the ileocecal portion of the bowel and ileocolic anastomosis with sutures.

CASE 9 (Cooper-Foster[20]).—A child of 5 years had an umbilical fecal fistula which was purported to be of a tuberculous origin. Ramsay Smith, however, doubted the tuberculous nature of the condition and, apparently, Cooper-Foster was also uncertain on this point. This case, therefore, must be looked on as a questionable example of a tuberculous Meckel's diverticulum.

Cases 8 and 9 are doubtful cases.

AUTHOR'S CASE

CASE 10.—A. G., a man, aged 23, an Arabian, was admitted to the second surgical division of Bellevue Hospital, service of Dr. Hartwell, March 3, 1922, with the chief complaint of pain in the right lower quadrant of four months' duration.

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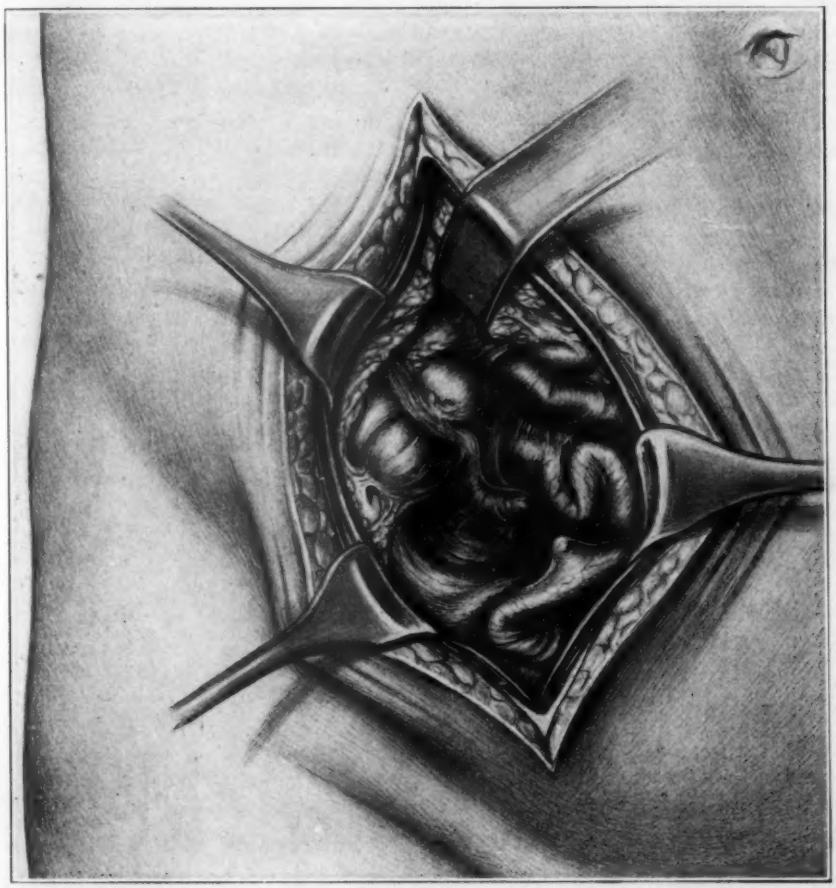
19. Ricketts, cited by Porter (Footnote 8). From the meager description available, in this case report, it seems to have been an example of a tuberculous peritonitis with an incidental finding of a Meckel's diverticulum and not one primarily involved in a tuberculous process.

20. Smith, Ramsay: Edinburgh M. J., 1893, p. 744.

Four months before admission, while pushing a cart, the patient felt pain in the right lower quadrant, and for the last two months, he had been unable to continue his work. Vomiting had been a prominent symptom, occurring at intervals during the last four months, and for the last four days had been persistent, coming on about one-half hour after meals. The vomitus was yellow and never bloody. He had coughed up bright red blood on several occasions. The patient had never been jaundiced; the bowels had been markedly constipated, moving only once every three days.



Tuberculosis of Meckel's diverticulum and appendix (author's case).

The gastro-intestinal history revealed that the patient had had "catarrh of the stomach" two years before, and had been one week in the hospital, during which time he vomited considerably. He stated that he was cured. The appetite had been good up to the present illness; no constipation had been present until the present illness, and no melena. The genito-urinary history revealed gonorrhea ten years before with epididymitis and arthritis of the knee; there was no chancre.

The parents were living and well; twelve brothers were dead, one having died of tuberculosis.

Physical examination showed a poorly nourished, well built, young negro adult, acutely ill. The pupils were equal and regular, and reacted to light and in accommodation. The ears and nose were negative. The teeth were in fair condition; the tongue was coated; the breath was foul. The neck was negative. The heart was negative. Over the right apex of the lungs posteriorly, no dulness or râles were present, but prolonged expiration and harsh breathing were noted. There was moderate tenderness over the entire abdomen, particularly in the right lower quadrant; rigidity, at this point, though not marked, was present to a slight extent, and a mass could be felt about 2½ inches (6.2 cm.) long and three-fourths inch (1.8 cm.) wide.

The provisional diagnosis was: (1) tuberculosis of the cecum; (2) hyperplastic tuberculous peritonitis; (3) a new growth of the cecum, and (4) subacute appendicitis with an abscess of the appendix.

An operation was performed, March 4, 1922. When the peritoneal cavity was opened, the mass described above was found to consist of the appendix and a portion of the cecum, covered anteriorly by adherent omentum containing a small abscess cavity from which odorless green pus to the amount of 1½ ounces (4.5 c.c.) was evacuated. The appendix was bulbous, thickened, and covered with fibrinous exudate; the surface was reddish brown in appearance, and, on palpation, the appendix was firm and thicker than normal. Internally to the abscess cavity and slightly below it, a pouchlike diverticulum of the terminal ileum was found, which, however, was not adherent to the appendix or cecum but occupied a position just mesial to the abscess cavity. It was, apparently, lying entirely free in the peritoneal cavity. Its proximal portion, where it became continuous with the ileum, did not appear unlike the normal adjacent intestine; however, the distal end, which was about the size of the tip of the thumb, was thickened, irregular, nodular in appearance, and in color was somewhat darker and more hemorrhagic than the normal small intestine. As far as could be determined from a limited examination at the time of operation, there were no other tuberculous intestinal lesions.

Gas and oxygen anesthesia without ether was used. An appendectomy was performed in the usual manner using actual cautery for removal of the appendix, and invaginating the stump with a purse-string suture reinforced by a peritoneal (Lembert) suture. Excision was done of Meckel's diverticulum. Closure of the small intestine defect was made by two layers of fine chromic catgut. The abdominal incision was closed in layers with a rubber dam drain to the base of the appendix.

Pathologic examination by Dr. Morton Ryder (resident pathologist, second surgical division, Bellevue Hospital) of the appendix and Meckel's diverticulum revealed:

1. An appendix measuring 5 cm. by 12 mm., slightly curved, of fairly even caliber except at the base, which was slightly smaller than the rest. The surface was darkened and roughened by adherent fibrinous exudate. A section showed a lumen present throughout, eccentrically placed.

2. A thimble shaped piece of tissue, apparently a blind pouch of intestine, 12 mm. long and 12 mm. in diameter. The surface was dark and roughened, like that of the appendix, by adherent exudate. Its lumen was filled with recent blood clot.

Microscopic examination revealed:

1. Sections of the appendix showed a normal lumen with crypts of moderate depth. The lymphoid tissue was abundant and the follicles were well preserved. The epithelium was intact in the sections studied. One section showed a solitary tubercle in the lymphoid layer. In some sections, the submucosa was remarkably thickened by a growth of discrete and conglomerate tubercles, showing slight central necrosis. This thickening was eccentric. In other sections, both muscularis and submucosa were thickened and distorted by overgrowth of relatively acellular connective tissue in which there was a moderate infiltration with round cells, especially about the blood vessels. The subserosal layer was markedly thickened by recent granulation tissue, edematous, richly infiltrated with polymorphonuclears and with a scattering of miliary tubercles. At one point on the serosa was a mass of polymorphonuclears with some fibrin.

2. Sections of the diverticulum showed a moderately thickened wall of ileum, with discrete and conglomerate miliary tubercles in the submucosa. Giant cells were numerous, and a few of the tubercles had small central areas of necrosis.

The diagnosis was tuberculosis of the appendix; acute suppurative periappendicitis, and tuberculosis of the diverticulum of the ileum, probably Meckel's diverticulum.

A culture produced *Bacillus coli.*

Following the operation, the patient's temperature and pulse remained satisfactory, except for a slight elevation on the seventh day, which, apparently, was due to imperfect drainage. About one week after the operation, the patient began to cough up sputum which, on examination, was found to contain large numbers of tubercle bacilli. The drains were gradually shortened and entirely removed at the end of eight days. A small sinus running down to the rectus sheath and thence upward persisted for another week.

Examination of the blood revealed that the white blood cells totaled 11,000; polymorphonuclears, 71 per cent., and hemaglobin, 70 per cent.

On his twenty-first postoperative day, the patient was transferred to the tuberculosis ward, and, two days later, was discharged to the Metropolitan Hospital. At this time, the physician in charge of the tuberculosis ward noted probable infiltration of the right upper lobe and upper third of the left lower lobe.

A report received from the Metropolitan Hospital stated that the patient died, May 8, 1922, of chronic pulmonary tuberculosis and tuberculous enteritis.

CONCLUSIONS

1. Meckel's diverticulum is the seat of a wide variety of pathologic conditions. Occurring in from 1 to 2 per cent. of all persons, it is found involved in from 25 to 33 per cent.

2. Tuberculosis of Meckel's diverticulum is a rare condition, only nine examples having been previously reported, of which two are doubtful. I present a tenth case.

3. As in tuberculous enteritis, the condition is usually, although not always, associated with advanced pulmonary tuberculosis.

4. Tuberculosis of Meckel's diverticulum alone without other involvement, either intestinal or pulmonary, has not been proved to exist.

5. The ultimate prognosis is uncertain and probably depends largely on the degree of other intra-abdominal involvement, and on the extent of the process in the lungs. The immediate prognosis in the cases operated on is fair. Of the six cases in which the result is stated, three of the patients recovered and three died.

6. As far as can be determined from the literature, a correct preoperative diagnosis has never been made.

7. Simultaneous tuberculous involvement of the appendix and the diverticulum of Meckel, as in the case here reported, has not been heretofore observed, as determined by a careful search of the literature. The explanation is offered that, being back eddies in the fecal current, they offer a favorable site for the lodgment and subsequent invasion of swallowed tubercle bacilli.

UNUSUAL CONDITIONS IN THE DUODENUM AND THEIR SIGNIFICANCE

MEMBRANOUS OBSTRUCTION OF THE LUMEN, DIVERTICULA AND CARCINOMA *

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A tabulation of known unusual conditions in the duodenum is evidence that the theme is a large one. Included in the list are (1) conditions resulting from misdirected developmental processes, and (2) conditions resulting from injury or disease. In the first group are anatomic variations of all types, including abnormal position, mobility, blood supply and peritoneal relations of the organ, various forms of complete or partial obstruction, and primary diverticula. In the second group are obstructions caused by foreign bodies, impacted gallstones, or intestinal parasites, acquired diverticula, and both benign and malignant tumors of the duodenum. Such lesions are not only of academic interest, they are also of practical importance in the diagnosis and treatment of obscure, and sometimes apparently simple diseases. I have selected for brief consideration here three unusual conditions; membranous obstruction of the lumen of the duodenum in an adult, diverticula, and carcinoma of the duodenum.

MEMBRANOUS OBSTRUCTION OF THE LUMEN OF THE DUODENUM: REPORT OF A CASE

History.—A man, aged 72, had complained of indigestion since childhood. His symptoms were indefinite; epigastric distress without real pain, made worse by coarse and sour foods, abdominal distention, belching, and constipation were the outstanding ones. The attacks came periodically, lasted for periods of from one to several months, and were absent for intervals of about equal length. In the last year, the patient's condition had grown much worse; he had limited his diet to soft foods and liquids, but without relief. There was nothing in his history to suggest gastric retention; he had vomited only occasionally even during the last year.

Examination.—The patient showed his years; he was stoop shouldered, short in stature, had an emphysematous chest and spadelike hands, and the scarcity of axillary and pubic hair suggested an internal glandular disturbance. Tenderness on pressure in the right hypochondrium was the only abdominal physical finding of note. The systolic blood pressure was 160, and the diastolic 86.

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* Observations made under the supervision of Dr. H. E. Robertson in the Department on Pathologic Anatomy and Dr. D. C. Balfour in the Division of Surgery, Mayo Clinic. Read before the California Medical Association, Los Angeles, May 12-15, 1924.

Examination of the blood revealed a slight secondary anemia. The Wassermann reaction was negative. One test meal gave a total gastric acidity of 42 with free acid 24, and a total volume of 950 c.c. in which a few food remnants were found. A second test gave a total acidity of 42 and a free acid content of 32 in a total volume of 475 c.c. in which no food remnants or blood were found. The roentgen-ray examination disclosed a dilated stomach, but no demonstrable lesion. Pyloric obstruction of unknown origin was the diagnosis. The patient's rapid decline under medical care and the conclusive laboratory proof of high intestinal obstruction were deemed sufficient indications for operation.

Operation.—The first portion of the duodenum, stomach, and lower esophagus were found greatly dilated. The upper half of the stomach appeared to have been partially invaginated into the dilated esophagus, or through an abnormally lax esophageal hiatus, and was apparently lying in the left pleural cavity. The stomach was easily pulled downwards into place, and was fastened by a few sutures to the lower end of the abdominal wound. No other abnormalities were noted by the surgeon, who was prohibited, by the critical condition of his patient, from searching further, after the apparent causative factor of the symptoms had been found and corrected. The patient did well until the eighteenth day after the operation, when he developed acute dyspnea and cyanosis, and died in a few minutes.

Necropsy.—At necropsy, the immediate cause of death was found to be a large pulmonary embolism. The operative site was in good condition. The lower third of the esophagus, stomach, pylorus and the first portion of the duodenum were greatly dilated, their walls thick and firm. The stomach was in the normal position, but its fundus could easily be invaginated into the distended esophagus. A few old fibrous adhesions at the left apex, a small hyaline, partially calcified plaque in the right parietal pleura, and a few calcified nodes at the hilums were the only direct evidences of an old tuberculous infection. In the lower end of the esophagus there was a small mucosal ulceration, possibly the result of pressure from the pseudodiaphragmatic hernia previously described. There were no lesions of the mucosa of the stomach. The dilatation of the duodenum appeared to end abruptly 12 cm. from the pylorus, the bowel from there on being of normal diameter. No obstruction could be seen externally to account for this condition. The peritoneum of the dilated portion merged evenly with that of the normal bowel below. Its surfaces were smooth and glistening; there was no constricting band, and nothing to explain the dilatation. When the bowel was opened from above, its lumen was seen to be partially closed, 1.5 cm. above the ampulla of Vater, by a transverse septum slightly concave above, 5 mm. in thickness at its attachment, and tapering down toward its center, where, eccentrically placed, was on oval opening 8 mm. in its greatest diameter (Fig. 1). Grossly and microscopically, the membrane was found to consist of normal mucosa and submucosa overlying a connective tissue layer, with a few muscle fibers from the bowel coats turning into it at its base. Careful search did not reveal evidence of gastric or duodenal ulceration, old or recent. There was no direct evidence of old or recent inflammation, either tuberculous or of any other type, to account for its formation. The long history of intestinal trouble and the thick-walled dilated alimentary tract above pointed to its early origin. The pseudodiaphragmatic hernia could scarcely have been a factor in the cause; it was probably a result of hyperperistalsis with dilatation of the esophagus and stretching of its diaphragmatic hiatus. Again, if the obstruction had formed in later life, it would surely have manifested itself by the more toxic symptoms so typical of high intestinal obstructions. That there was at least a relative increase in the

degree of stenosis with advancing years is more than probable. This is borne out by the more recent increase in the severity of the patient's symptoms, although here the formation of the internal hernia may have also played its part.

Anatomically, the membrane causing the obstruction resembles those of congenital origin sometimes found in infants and occasionally in adults. Probably it was developmental rather than strictly congenital in origin, and it may have formed at any period in the prenatal or early postnatal growth of the individual.

CASES REPORTED IN THE LITERATURE

Very few such cases in adults have been reported. Moore [1] describes a constriction at the duodenojejunal angle in a specimen from a man aged 40, which consisted of an internal ring of mucous membrane just admitting the little finger. The peculiarity had not given rise to symp-

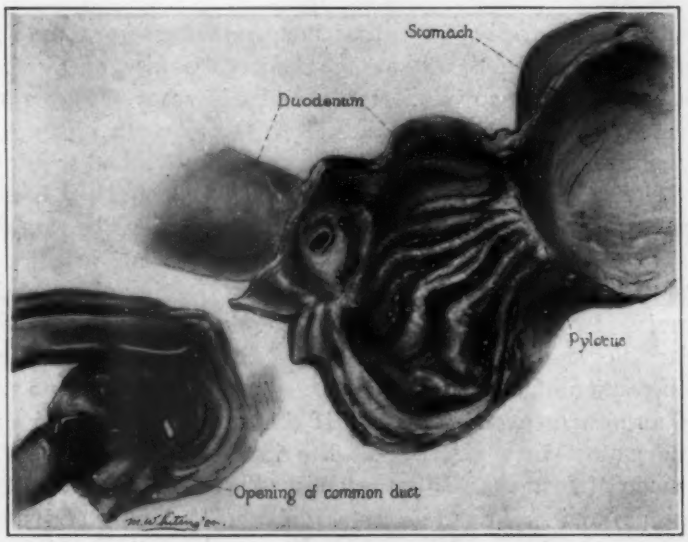

Fig. 1.—Membranous stenosis of the lumen of the duodenum.

toms and was, according to Moore, obviously a variation from normal development, and not the result of any morbid change. Silcock's [2] case (found at necropsy) was that of a woman, aged 34; the septum, 15 cm. below the pylorus, projected downward into the lumen of the intestine and resembled in size and shape the thumb of a glove. An opening in its center barely admitted the tip of the little finger. Wilkie [3] has seen

1. Moore, N.: Multiple Diverticula of the Small Intestine with Congenital Stricture of the Duodenum, Tr. Path. Soc. London **35**:202-204, 1884.

2. Silcock, A. Q.: Epithelioma of Ascending Colon; Enterocolitis; Congenital Duodenal Septum, with Internal Diverticulum, Tr. Path. Soc. London, **36**:207, 1885.

3. Wilkie, D. P. D.: Duodenal Diverticula and Duplicature of the Duodenal Wall, Edinburgh M. J. **11**:219-229, 1913.

three such developmental deformities in the bodies of adults at postmortem. Keith [4] observed, in an adult museum specimen, a diaphragm above the opening of the common bile duct, which was ballooned downwards into the second part of the duodenum, and had an oval orifice 5 by 3 mm. in diameter. Terry and Kilgore [5] operated on a man, aged 24, whose condition had been diagnosed clinically as pyloric stenosis. They found the stomach and the first part of the duodenum dilated, but there was no local thickening of the intestine and no abnormalities of the peritoneum to explain the constriction. The patient died on the fifth day following operation, and necropsy disclosed an obstructing fold in the duodenum, which was believed to be of congenital origin, as nothing was found to indicate that it had arisen on the basis of any morbid change.

Two types of atresia of the duodenum in the new-born are described in the literature. In the first, the direct continuity of the bowel is interrupted, leaving two blind ends completely separated by a variable distance, or joined by a narrow strand of fibrous tissue. In the second type, the bowel remains a single unit externally, but the lumen is blocked by a transverse septum of varying thickness. Both types of obstruction are found most commonly above the ampulla of Vater, but at times they are found below it. In some instances, there is a duplication of the common duct, with an opening above and below the atresia. In the majority of cases, the obstruction is complete, and the infant dies shortly after birth. Partial obstructions may occur either as a constriction of the intestine at one or more points, or as a perforation of an obstructing membrane. If there is an opening of sufficient size, the patient may reach adult life in comparatively good health. Their mode of formation is not established. Pathologic processes, such as fetal peritonitis, intussusception, volvulus, enteritis and abnormal developmental processes, have all been held responsible. If there is a transverse septum, it is thought to be merely an abnormally developed circular fold, or the result of a failure of complete regression of a developmental process, first described by Tandler [6] as of normal occurrence, in which, during early embryonic life, the lumen of the duodenum, at first patent, is closed for a short period by an overgrowth of its epithelial lining. It is difficult to conceive, however, how a thin, uniform membrane can result from an irregular regression of a diffuse growth of epithelium (Fig. 2). Such a membrane can be more simply explained

4. Keith, A.: Constrictions and Occlusions of the Alimentary Tract of Congenital or Obscure Origin, Brit. M. J. **1**:301-304, 1910.

5. Terry, W. I., and Kilgore, A. R.: Congenital Stenosis of the Duodenum in an Adult, J. A. M. A. **66**:1774-1776 (June 3) 1916.

6. Tandler, J.: Zur Entwicklungsgeschichte des menschlichen Duodenum in frühen Embryonalstudien, Morphol. Jahrb. **29**:187-216, 1900.

by imagining a slight telescoping of the bowel with knuckling of the mucosa sufficient to form a complete membrane by adhesion of its edges, or leaving a small opening, if the degree of invagination is less. In the early embryo, fixation of the bowel after invagination could easily occur, and yet leave little sign on its peritoneal surface by which the process could later be identified. This process would produce the membranes described, and, considering the extensive movements of the bowel during intestinal rotation and the adhesive powers of the normal peritoneum at so early a stage, the explanation seems quite plausible.[7] It is presented, however, with reserve, for, although a multiplicity of theories given to explain a single fact usually proclaims our ignorance of its true cause, nevertheless an attempt to assign in each instance a single cause for any oddity in nature may lead us further from the

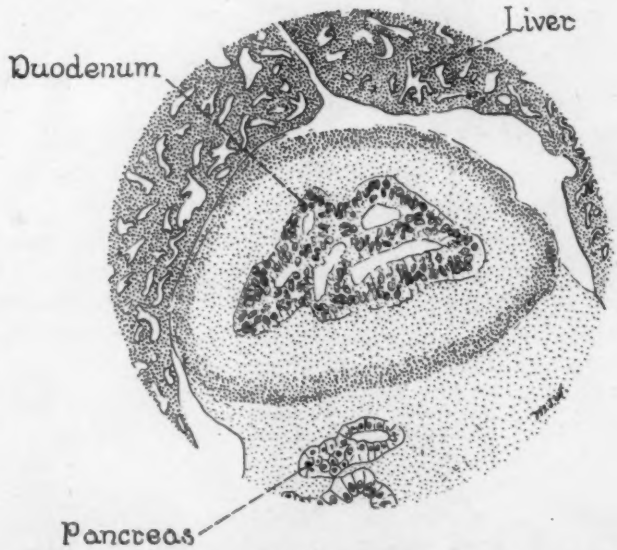

Fig. 2.—Partial occlusion of the duodenum below the opening of the common duct in a human embryo 18 mm. long (from Dr. Scammon's collection No. 260, University of Minnesota).

truth. Thus, in the formation of the obstructions here described, no single factor may be proclaimed the chief factor concerned, but it is likely that many contribute their share, in each instance differently proportioned, toward the whole.

General interest in chronic as well as in acute high intestinal obstructions is increasing. The condition described is extremely rare, but it should be considered whenever the cause of a chronic duodenal obstruction is obscure.

7. Nagel, G. W.: Right Paraduodenal Hernia, J. A. M. A. **81**:907-912 (Sept. 15) 1923. Toldt, C.: Bau und Wachsthumsveränderungen der Nekröse des menschlichen Darmkanales, Ed. 2, Vienna, Tempsky, 1889.

DUODENAL DIVERTICULA

Duodenal diverticula have long been known as occasional inconsequential findings at necropsy. In more recent years, the roentgen ray has added to their apparent number and given certain of them a definite place in clinical medicine. In recent literature, the reported cases have been extensively reviewed, various types described, their possible etiology considered, and single cases recorded, together with the symptoms and the operative procedures adopted for relief.[8] A review of the cases seen at the Mayo Clinic led to their division into two main groups, developmental and acquired.

Twenty duodenums showing diverticula of the developmental type were found in a series of necropsies at the Mayo Clinic (2.2 per cent. of the necropsies performed between July, 1922, and February, 1924). Fourteen had single pockets, while in six, two pockets were present, making a total of twenty-six diverticula. All were found in adults, the oldest patient being aged 87, the youngest 33 (average age 61 in nineteen cases). Twelve were found in males, and eight in females. All were located within a radius of 3 cm. of the ampulla of Vater; only four were below it and the remainder either to one side or just above the opening of the common duct. In several, the ampulla itself was in a shallow depression into which the true diverticulum opened. In size they varied from a few millimeters in diameter and depth to narrow pockets 6 cm. long (Fig. 3), the approximate average depth being from 1 to 2 cm. A number lay directly along the course of the common duct, separated from it by loose areolar tissue (Fig. 4). Some had wormed their way between the head of the pancreas and bowel wall. The latter were the largest, ballooning outwards from

8. Andrews, E. W.: Duodenal Diverticula, J. A. M. A. **77**:1309-1311 (Oct. 22) 1921. Basch, S.: Diverticulum of the Duodenum, with a Report of a Case Diagnosed During Life and Successfully Operated on, Am. J. M. Sc. **153**:833-841 (June) 1917. Case, J. T.: Diverticula of the Small Intestine, Other than Meckel's Diverticulum, J. A. M. A. **75**:1463-1470 (Nov. 27) 1920. Cole, L. G., and Roberts, D.: Diverticula of the Duodenum, Surg., Gynec. & Obst. **31**:376-382 (Oct.) 1920. Cole, L. G., and Steiner, J. M.: The Technical and Clinical Use of the X-Ray, in Keen's Surgery, Philadelphia, Saunders, **8**:764-804, 1921. Cullen, E. K.: Report of a Diverticulum of the First Portion of the Duodenum, Tr. South. Surg. Assoc. **33**:364-369, 1920. Downes, W. A.: Duodenal Diverticula, Ann. Surg. **76**:43-51 (July) 1922. Jones, W. M.: Duodenal Diverticulum with Ulcer on the Opposite Wall, J. A. M. A. **78**:1706-1707 (June 3) 1922. Maclean, N. J.: Diverticulum of the Duodenum, Surg., Gynec. & Obst. **37**:6-13 (July) 1923. Moore, E. C.: Duodenal Diverticula, with Report of a Case, Arch. Surg. **1**:513-523 (Nov.) 1920. Murchison, D. R.: Duodenal Diverticulum with Pyloric Ulcer, J. A. M. A. **75**:1329-1330 (Nov. 13) 1920. Ritchie, H. P., and McWhorter, G. D.: Duodenal Diverticula, with Report of a Case Associated with a Duodenal Ulcer, Surg., Gynec. & Obst. **25**:485-489 (Nov.) 1917. Spriggs, E. I.: Duodenal Diverticula, Brit. J. Surg. **8**:18-26 (July) 1920.

pressure of their fluid contents, with only intra-abdominal tension and the elasticity of their thin walls to limit their extent. All were closely associated with the pancreas; many were completely buried in its substance, a smooth recess lined with a little areolar tissue being formed for their reception. None showed evidence that inflammatory processes had been factors in their production. The majority included only the mucosa and submucosa in their walls, excepting at the base, where they were clothed to a varying extent by strands of muscle fibers. The mucosa and submucosa were generally quite normal, although a few

Fig. 3.—Large diverticular hernia of the duodenum; probe in common duct.

showed small collections of lymphocytes as evidence of slight chronic infection. In the smaller ones, the mucosa did not appear stretched, and although there were no large folds, numerous small knucklings were present. Normal villi and intestinal glands were found in the majority of cases, but only a few showed isolated duodenal glands. All were incidental findings at necropsy, and, so far as could be determined, had not given rise to symptoms. Other congenital anomalies in the form of an accessory spleen, pancreas, and complete duplication of one ureter were found in three instances at necropsy. Associated pathologic conditions present in others were ulcers of the duodenum in two cases,

and of the stomach in one case. In four cases, there were multiple diverticula of the colon, and in one of these multiple jejunal diverticula also. The ulcers were in the first portion of the duodenum far removed from the diverticula and were not factors in their formation. The associated diverticula of the small and large bowel indicated developmental weaknesses in certain portions of the intestinal musculature of these patients.

The foregoing types of diverticula have variously been described as being of congenital origin, or representing mere diverticular hernias of the bowel, a counterpart of those seen more often in the descending and sigmoid colons.[9] Wilkie,[3] Lewis and Thyng have upheld the congenital theory of their origin. Lewis and Thyng [10] have demonstrated multiple duodenal buds and diverticula in embryos, the persistence of which would explain their occasional occurrence in the adult. Keith [11]

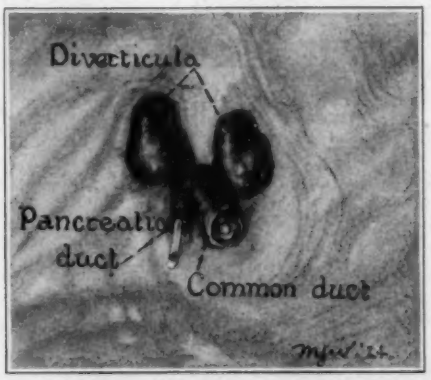

Fig. 4.—Two small diverticula near the common duct (dissected specimen).

believes that most of them represent mere diverticular hernias through weak portions in the bowel wall, namely, where the latter is pierced by ducts or vessels. According to him, the herniation is the direct result of increased pressure within the bowel, common in enteroptotic individuals where partial duodenal obstruction may be produced by a direct drag of the mesentery where it crosses the duodenum, or by a

9. Mahler, R.: Personal communication. Mayo, W. J.; Wilson, L. B., and Giffin, H. Z.: Acquired Diverticulitis of the Large Intestine, Surg., Gynec. & Obst. **5**:8-15, 1907.

10. Lewis, F. T., and Thyng, F. W.: The Regular Occurrence of Intestinal Diverticula in Embryos of the Pig, Rabbit and Man, Am. J. Anat. **7**:505-519, 1907-1908.

11. Keith, A.: Diverticula of the Alimentary Tract of Congenital or of Obscure Origin, Brit. M. J. **1**:376-380, 1910; On the Origin and Nature of Hernia, Brit. J. Surg. **11**:455-475 (Jan.) 1924.

sphincteric action of muscle at the termination of the duodenum, which Keith believes is of even more frequent occurrence. A few of these diverticula may be of true congenital origin, representing remains of the buds described by Lewis and Thyng. The majority are probably developmental, forming, as Keith suggests, at weak points in the bowel wall and forcing their way early into the head of the pancreas. That many of them enlarge in adult life and some have their beginning at this period is very likely true. The largest diverticula we found were in patients of advanced age in whom all the tissues were stretched and nonelastic. Whatever the time of their appearance, the majority are formed on a developmental basis in that they occur at actual or potential, congenital weak points in the bowel wall. Bearing this in mind, Keith's designation of them as diverticular hernias is most appropriate.

None of the developmental diverticula in the Mayo Clinic series had given rise to symptoms, but that they might become inflamed and even at times produce obstruction is a quite reasonable assumption and one borne out by numerous case reports in the literature. The relative sterility of the duodenal contents may be a factor in keeping the condition generally benign.

Acquired diverticula form a more important group. Nineteen of this type verified at operation have been gathered from the files of the clinic.[12] Of these, ten were in male patients, nine in females. The average age was 46, the oldest patient being 64, and the youngest 25. All the diverticula of this group were situated in the first portion of the duodenum. Three were found associated with gallbladder disease; in two patients the diverticulum appeared to have formed as a result of the closure of a fistulous tract between the two organs. In one of the patients, gallstones were present in the diverticulum. Two diverticula were found in patients operated on for chronic appendicitis, in whom the traction of adhesions around the duodenum was probably the factor producing the diverticula. The fourteen remaining were definitely associated with duodenal ulcers.

Any morbid process about the duodenum which produces adhesions or scar tissue in the wall itself may more or less distort the wall of the bowel. Small shallow outpocketings, however, are not considered in this list, and only those are included which are true outpouchings of the bowel wall, with relatively narrow openings into the lumen of the intestine. Carman [13] says that this type occurs in less than 1 per cent. of all duodenal ulcers. Cole [14] believes they occur more frequently than is

12. A complete study of duodenal diverticula is being made by Dr. V. C. Hunt, who has allowed me to use this material.

13. Carman, R. D.: The Roentgenologic Diagnosis of Duodenal Ulcer, Am. J. Roentgenol. **3**:252-256 (May) 1916.

14. Cole (Footnote 8, fifth reference).

generally conceded. The majority form just beyond the pylorus in the anterior-inferior portion of the duodenum. All coats of the bowel are included in their walls, and they are not due to perforation of the base of an ulcer and the resulting formation of a false pouch, but they are formed by the contraction of scar tissue and by pressure from within the bowel. That considerably more contraction may occur in the scars of the duodenum than is immediately apparent has been shown by Robertson and Hargis [15] who have measured the distance between the pylorus and the ampulla of Vater as a standard in a large number of specimens, and have found that, in patients with duodenal ulcers and even in those with only minute scars, the distance has been relatively shortened by several centimeters. The most common site of ulcers is along the superior border of the duodenum just below the pylorus, and, as a result, most of the shortening takes place here, leaving the lower border redundant and favorable for the formation of a diverticulum. The diverticula are apparently not directly involved in the inflammatory process; the peritoneal surface was described as smooth and free from adhesions in nearly every instance. The roentgen ray occasionally shows what appears to be a diverticulum, although none can be found at operation or at necropsy. This phenomenon is due to muscle spasm. A true diverticulum represents the result of this spasm continuing over a long period, abetted and aided by contracting fibrous tissue.

In this series, a diverticulum was diagnosed by means of the roentgen ray in five patients, while in eleven only the primary lesion was noted. In three, roentgen-ray examination of the gastro-intestinal tract was not made. The pockets varied from 1 cm. in diameter and depth to 4 cm. in length and 1.5 cm. in width, the dimension of one pocket. In general, they were more globular in form than those of the developmental type, and frequently the surgeon compared them in size and shape to English walnuts or small tangerines (Fig. 5). The symptoms are those of the primary lesion; the fact that many of the patients gave atypical histories of duodenal ulcer can hardly be considered significant, since this is true of many uncomplicated cases also.

Operative treatment was made to suit the individual exigencies demanded in each case. In simple cases with small diverticula, a posterior gastro-enterostomy only was performed, or other operative measures were carried out to relieve the primary condition, the diverticula being left alone. In two instances, the diverticula were inverted into the lumen of the intestine and secured by mattress sutures at their bases. The pouch of one was trimmed before inversion. In two others, the diverticulum was made use of in enlarging the pyloric opening while

15. Robertson, H. E., and Hargis, E. H.: Personal communication.

a Finney [16] pyloroplasty was performed (C. H. Mayo). In one, a V-shaped plastic operation was performed on the pouch. In two, a pylorectomy with removal of the ulcer area and diverticulum was performed. Of the nineteen patients, seven were well from several months to eight years after the operation. Four have not been heard from, or sufficient time has not elapsed from which to draw conclusions as to their state. One had recurrent, small gastric hemorrhages, but no other symptoms; another had a return of symptoms after several years of freedom; these proved to be caused by a gastric ulcer, which was excised with an excellent result. Five patients were greatly relieved, but occasionally had to be careful of their diet. In none of the latter was

Fig. 5.—Diverticulum secondary to duodenal ulceration and scar tissue contraction (reconstructed).

anything done to the diverticulum, but this cannot be regarded as of extreme significance in view of the fact that these cases were otherwise complicated. Four patients in whom the diverticulum was not touched remained well after standard operative procedures had been carried out for the underlying disease. One patient died shortly after the operation, and, in this case, the diverticulum, situated in the usual position just below the pylorus, had been turned in and a posterior gastro-enterostomy made. Death resulted from peritonitis. The inverted diverticulum had

16. Finney, J. M. T., Surgical Treatment of Diseases of the Stomach, cited by Ochsner, A. J.: Surgical Diagnosis and Treatment, Philadelphia, Lea and Febiger, **2**:703-762, 1921.

become somewhat edematous and formed a polypoid mass completely blocking the pylorus. This was of no serious consequence to this particular patient. It should be remembered, however, in patients in whom no gastro-enterostomy is made, and in those in whom the diverticulum is near the ampulla of Vater, that marked obstruction may follow its inversion.

To sum up, we find that secondary duodenal diverticula may form from the closure of fistulous tracts, traction of adhesions from without, or as is most frequently the case, from scar tissue contraction of the bowel wall with increased pressure from within. A preoperative diagnosis can only be made with the aid of the roentgen ray. At operation small noninflammatory pouches may be ignored or inverted into the lumen of the bowel. Large diverticula would best be trimmed before inversion, or removed by some type of plastic operation.

CARCINOMA OF THE DUODENUM

Carcinomas of the duodenum may be divided broadly into primary and secondary. Both forms are rare, and several theories have been advanced in attempted explanation of this fact. Until our knowledge of the origin and nature of carcinomas in general is better founded, such reasonings remain purely hypothetical, and will not be considered here. The apparent resistance of the duodenum to malignancy is strikingly displayed in carcinomas of the stomach where the tumor, frequently arising close to the pylorus, almost invariably appears to stop abruptly at the pyloric ring. This has been thought to be due to a scarcity of lymphatic vessels communicating between the two organs, to the upward flow of lymph from duodenum to stomach, or to obliteration of tissue spaces by spasmodic contraction of the muscle, this forming a mechanical obstruction to the advance of the carcinoma. This freedom, however, may be more apparent than real, and the assumption that the pylorus is an impenetrable barrier to the advance of malignant growths is false, occasionally leading to grave errors in diagnosis and treatment. Konjetzny,[17] in fifty-four cases of carcinoma of the pylorus, found macroscopically that the duodenum was invaded in twenty-three (42 per cent.). Brinton's and Maragliano's figures are lower, ten in 125 cases (8 per cent.) and two in twelve cases respectively, while Borrmann [18] found involvement of the duodenum in twenty of a total of sixty-three specimens, all of which were operative resections and, therefore, of comparatively recent origin. In fourteen necropsy speci-

17. Anschütz, W., and Konjetzny, G. E.: Die Geschwülste des Magens, Deutsch. Chir. **1**:387 (Part I) 1921.

18. Borrmann, R.: Das Wachstum und die Verbreitungsweise des Magencarcinoms vom anatomischen und klinischen Standpunkte, Mitt. a. d. Grenzgeb. d. Med. u. Chir. Suppl. **1**:376, 1901.

mens of carcinoma close to the pylorus, I found malignant tissue to have spilled over the pyloric dam, involving the duodenal mucosa in three (Fig. 6). Microscopically, this number was increased by two. In these, the carcinomatous cells had extended down about 1 cm. into the submucosa of the duodenum. In all, the pylorus was identified as a prominent muscle ridge on longitudinal section. The number showing duodenal involvement in this series is high. The slight degree of extension present, however, in cases relatively advanced must strengthen rather than disprove the theory of the natural resistance of the duodenum to invasion by malignant growths.

Three additional specimens are of interest; in the first [19] there was a carcinoma of the lesser curvature of the stomach, which left the first

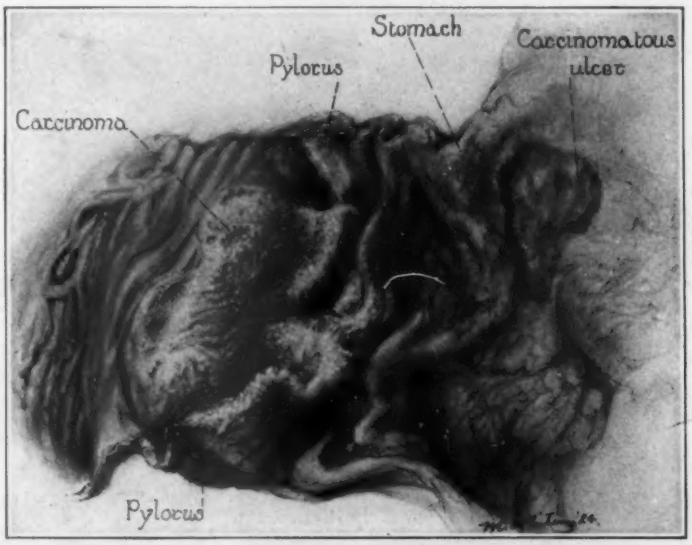

Fig. 6.—Carcinoma of the pylorus extending 2.5 cm. into the duodenum, and a carcinomatous ulcer of the stomach.

inch of the stomach above the pylorus grossly free. Beginning just below the pyloric ring on the duodenal side was a malignant papilloma with a base 2 cm. in diameter, and adherent to the head of the pancreas (Fig. 7). Whether the duodenal and gastric tumors were independent primary growths, or the one secondary to the other cannot be determined with certainty; the latter assumption, however, is the more plausible. In the second specimen, there was a carcinomatous gastric ulcer 2 cm. above the pylorus, while just below it was a carcinomatous

19. Judd, E. S.: Carcinoma of the Small Intestine, Journal-Lancet **39**:159-169 (April 1) 1919. Mayo, W. J.: The Prophylaxis of Cancer, Ann. Surg. **59**:805-814, 1914.

ulcer of the duodenum 1.5 cm. in diameter (Fig. 8). The true condition was not realized until microscopic examination had shown extensive carcinomatous invasion of the gastric and duodenal musculature contiguous to the ulcers, and the pyloric muscle between. The duodenal

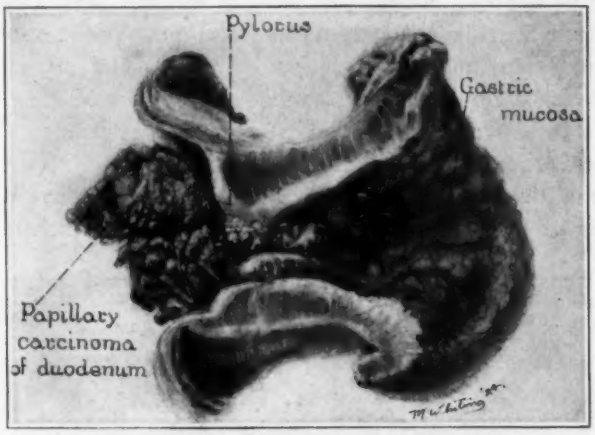

Fig. 7.—Malignant papilloma of the duodenum.

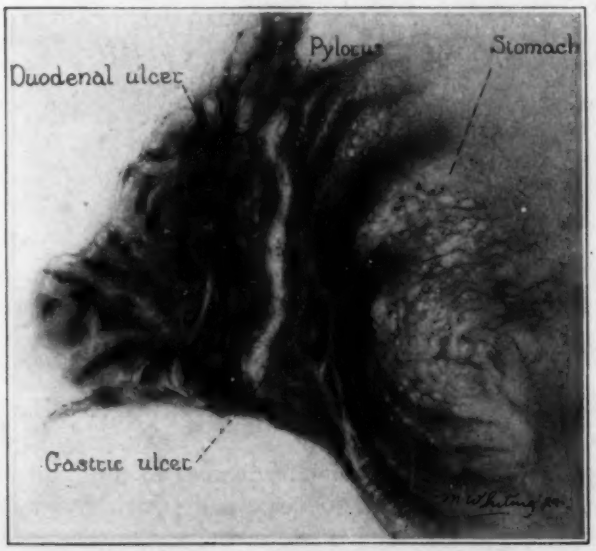

Fig. 8.—Carcinomatous gastric and duodenal ulcers (Fig. 9).

growth is probably a direct extension of the carcinoma of the pylorus. The malignant infiltration is particularly well marked in the duodenum (Fig. 9). Here are seen single columns of carcinomatous cells advancing with difficulty along narrow paths, compressed and flattened by

hindering walls of muscle and connective tissue. The picture resembles that condition of extensive scirrhous carcinoma termed "leather-bottle stomach," a term not applicable here. Direct invasion of the duodenum from without, as in carcinoma of the pancreas, or metastasis to surrounding lymph nodes is more common, although even this is rare. Even the presence of duodenal metastasis in abdominal carcinomatosis is an unusual finding, although I have seen examples of both types. One specimen is worthy of mention. The patient came to the clinic with a biliary fistula of five months' duration, following a cholecystostomy. At operation, a carcinomatous gallbladder, adherent to the stomach, was removed. The patient succumbed, and a carcinomatous mass was found surrounding the pylorus. The mucosa of the stomach was

Fig. 9.—High-power photomicrograph of an infiltrating type of carcinoma at the base of the duodenal ulcer (Fig. 8).

everywhere normal, but the duodenum had been invaded 2 cm. below the pylorus. The tumor was itself an oddity, considering its probable origin from the cylindrical celled epithelium of the gallbladder, in that it was found to be a squamous cell epithelioma of a fairly well-differentiated type (Fig. 10). This can only be explained on a basis of true metaplasia. A similar case of metaplasia in carcinoma of the gallbladder has been described by Broders and MacCarty.[20] Robertson [21] and Broders [22] have also known this change to occur in carcinomas of the uterus, stomach and lung.

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20. Broders, A. C., and MacCarty, W. C.: Epithelioma, Surg., Gynec. & Obst. **27**:141 (Aug.) 1918.

21. Robertson, H. E.: Personal communication.

22. Broders, A. C.: Personal communication.

Lesions of the duodenum, such as have just been described, are fortunately rare. The pylorus does form a limited defense against the advance of carcinomas, and the duodenum itself appears to shun their presence. Simple rules, therefore, governing the diagnosis and treatment of conditions in this organ should not be made complex. The possible presence, however, of malignant invasion of the duodenum necessitates a careful examination of this organ in all suspected cases.[23]

Primary carcinomas of the duodenum form a more distinct entity,[24] in spite of the fact that the early involvement of the head of the pancreas makes their true point of origin difficult, if not impossible, to determine with accuracy. This critical attitude has not always been adopted in cases previously reported in the literature. Nine cases from

Fig. 10.—High-power photomicrograph of squamous cell epithelioma that had invaded the duodenum.

the Mayo Clinic are here reviewed, two previously reported by Judd,[25] not with the claim that they are all true primary duodenal cancers, but because, in each, the problem presented is that of a malignant stenosis of the duodenum with little extension beyond the walls of the bowel. Carcinomas of the papilla of Vater, or those obviously arising in the pancreas, are not included. Six of the patients were men, and three, women; the oldest patient was aged 70, and the youngest was 42, the

23. Mayo, W. J.: Radical Operation for Cancer of the Pyloric End of the Stomach, J. A. M. A. **54**:1608-1612 (May 14) 1910. Moynihan, B. G. A.: Operations Upon the Stomach and Intestines, Oxford Surgery, New York, Oxford University Press, **2**:555-648, 1919. Finney (Footnote 16).

24. Swan, T.: Unpublished data.

25. Judd (Footnote 19).

average age being 57.88 years. Six of the patients had had symptoms for six months or less; the longest period given by the remaining three was one year. Three had had mild indigestion for a number of years previous to the onset of their real trouble, but the history was not sufficiently clear to justify a diagnosis. An analysis of the symptoms of which complaint was made warrants emphasis being placed on the following, which were present in various combinations and degrees

Fig. 11.—Carcinomatous obstruction of the terminal portion of the duodenum.

in the majority of the patients: vomiting, usually of a retention character; constant dull pain in the epigastrium, frequently worse after meals, and in three patients appearing definitely two or three hours after the ingestion of food; abdominal distention; belching, anorexia, weakness, and loss of weight. Jaundice was only observed in one patient at the time of the first examination in the clinic. A tumor was felt in two patients, and in another there was visible peristalsis.

The majority showed only a slight secondary anemia. Gastric analysis showed normal or low, combined and free acids in five patients, while in four there was no free hydrochloric acid. In all but two, there was definite evidence of gastric retention. The roentgen-ray examination disclosed large stomachs, but no definite lesions in two patients; the duodenum was found dilated in only two instances, and only in one was the point of obstruction definitely noted (Fig. 11). Carman [26] has emphasized the difficulty of diagnosis in this condition, especially in the supra-ampullary form. The roentgen-ray reports read: one case of carcinoma of the stomach; one case of duodenal ulcer; five cases of

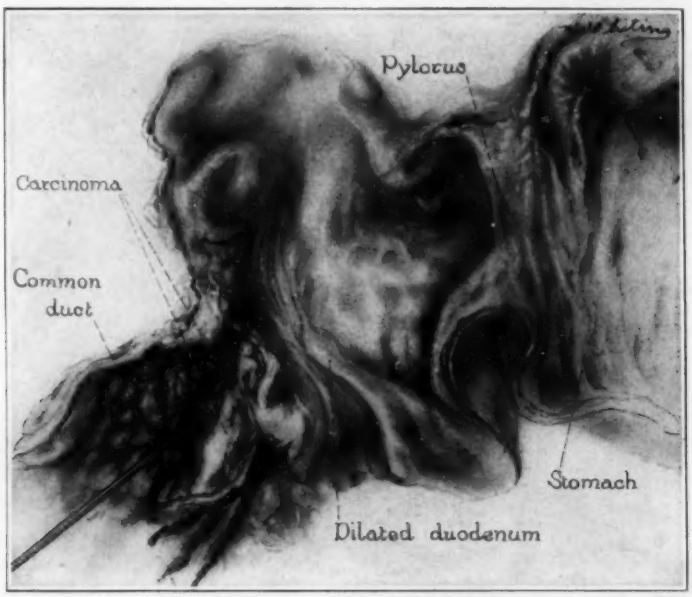

Fig. 12.—Cancer of the duodenum, with moderate involvement of the head of the pancreas.

indeterminate lesion; one case of lesion of the outlet. One patient was not examined by the roentgen ray. The clinical diagnoses were just as variable, and in only one case was a positive diagnosis of carcinoma of the duodenum ventured. Eight patients were operated on. In all, the lesion demonstrated was a stenosing tumor of the duodenum, situated above the ampulla of Vater in six instances, and below it in three. Two of these were near the duodenojejunal angle. All the operations were palliative; in five, posterior gastro-enterostomies were performed; in one, an anterior gastrojejunostomy; in one, a duodenojejunostomy,

26. Carman, R. D.: The Roentgen Diagnosis of Diseases of the Alimentary Canal, Ed. 2, Philadelphia, Saunders, 1920, p. 676.

and in one, an extensive pylorectomy without removal of the tumor, which was considered inflammatory, the operation being performed because of the presence of ulcers, with marked deformity of the duodenum. This patient died eleven months later, with signs of extensive abdominal malignancy. Two of the patients died shortly after operation, four within from three months to two years, and in one the ultimate result is not known. One patient writes a year after his operation that he is feeling fine, thus throwing some doubt on the correctness of the diagnosis in his case. Necropsy was performed in three cases: in two an annular, well limited constricting duodenal cancer was found, one above and one below the ampulla of Vater; in both there was moderate involvement of the head of the pancreas. In the third case, an indurated

Fig. 13.—Well differentiated adenocarcinoma of the duodenum.

ulcerative cancer with moderate stenosis and also pancreatic involvement were found (Fig. 12). In one, there was local glandular involvement, but in none was there evidence of other metastasis. Two of the four patients who died away from the clinic were said by their physicians to have died from abdominal carcinomatosis. No details of the symptoms immediately preceding death were available concerning two patients; that they died within two years after operation, barring death from intercurrent disease, seems to confirm the diagnoses. This leaves only two patients in whom the diagnosis of carcinoma may remain a doubt. The three tumors examined at necropsy, and a fourth at operation were adenocarcinomas. Microscopically, the three necropsy specimens varied from one fairly well differentiated form with irregular acinous structures lined by high columnar cells and intertwined with

connective tissue strands (Fig. 13) to one less differentiated, showing just a few gland-like structures and marked by areas of degeneration and local infiltration with lymphocytic cells (Fig. 14). The third represented a form about midway between these two.

This series of cases emphasizes the difficulty of diagnosis and the poor prognosis in tumors of this group. If they are encountered early their removal may be attempted. The duodenum is not a vital organ, and if adequate provision is made for the biliary and pancreatic secretions to enter the intestines, it can be removed in toto without apparent harm. This has been shown experimentally by Coffey,[27] Mann and Williamson,[28] and others, and wide resections in the human being have been made, especially in cases of carcinoma of the ampulla of

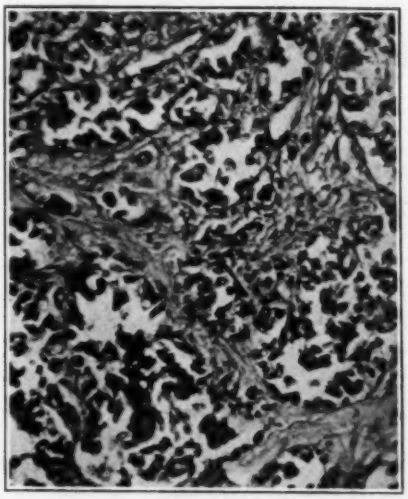

Fig. 14.—Poorly differentiated adenocarcinoma of the duodenum.

Vater, by Mayo, Judd, Kausch[29] and others with a certain degree of success. Such procedures, however hazardous, offer the only hope of cure.

CONCLUSIONS

These three unusual conditions in the duodenum are discussed:

1. A case of membranous stenosis in an adult is added to seven similar cases reported in the literature. Although rare, the possible

27. Coffey, R. C.: Pancreato-enterostomy and Pancreatectomy, Ann. Surg. **1**:1238-1264, 1909.

28. Mann, F. C., and Williamson, C. S.: The Experimental Production of Peptic Ulcer, Ann. Surg. **77**:409-422 (April) 1923.

29. Kausch, W.: Das Carcinom der Papilla duodeni und seine radikale Entfernung, Beitr. z. klin. Chir. **78**:439-486, 1912.

presence of such a condition should be considered if no other cause for a chronic high intestinal stenosis can be found.

2. Twenty-six duodenal diverticula of developmental origin are presented. All were incidental findings at necropsy. Nineteen diverticula secondary to diseases in or near the duodenum are described. The majority are associated with duodenal ulcers, and the symptoms are those of this disease. Small noninflamed diverticula require no treatment, but the larger ones should be inverted into the lumen of the bowel, or removed by a plastic operation.

3. Three specimens showing secondary involvement of the duodenum by malignant growths are described. Slight involvement of the duodenum was found in five of fourteen cancers of the pylorus seen at necropsy. Cancer of the duodenum is either secondary or primary. It is usually impossible even at necropsy to diagnose with certainty a primary carcinoma of the duodenum. Nine patients with malignant stenosis of the duodenum are presented. Such cases are difficult to diagnose clinically, and the prognosis is uniformly bad.

In considering diseases of the duodenum, their diagnosis and treatment, undue prominence should not be given these unusual conditions. A knowledge of rare lesions, however, forms an essential supplement to a thorough understanding of the diseases of any organ, and occasionally must prove useful in the practice of surgery.

THE SIGNIFICANCE OF THE PERICARDIUM IN RELATION TO SURGERY OF THE HEART *

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AND

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I. Introduction.
II. History.
III. Experiments and Comment.
1. The effect of mechanical trauma applied to the pericardium.
2. The effect of blood in the pericardial cavity.
3. The effect of hot salt solution applied to the heart and to the pericardium.
4. The effect of infection in the pericardial cavity.
5. The effect of tincture of iodin injected into the pericardial cavity.
6. The transplantation of fat into defects of the pericardium.
7. Heart tamponade. Report of two cases.
8. The effect of pericardiectomy.
IV. Summary.

I. INTRODUCTION

Following any surgical procedure on the heart, important and sometimes serious sequelae may arise which involve the pericardium or which may be dependent on its presence. The most important of these sequelae are (1) a rapidly forming pericardial effusion which may lead to fatal tamponade, and (2) cardiopericardial adhesions which commonly follow the subsidence of the effusion. The significance of these phenomena has been recognized repeatedly in experimental work carried out in this laboratory with the idea of developing a surgical procedure for the treatment of mitral stenosis. Further emphasis to the subject was given by the occurrence of a rapidly forming postoperative pericardial effusion in two cases of mitral stenosis in which operation was done by Dr. E. C. Cutler.[1] There are, furthermore, many cases of

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1. Cutler, E. C.; Levine, S. A., and Beck, C. S.: The Surgical Treatment of Mitral Stenosis, Experimental and Clinical Studies, Arch. Surg. 9:689 (Nov.) 1924. In Case 1, the formation of a pericardial effusion was indicated by changes in the size and shape of the cardiac shadow. It assumed its greatest extent on the third day following operation, having increased about 2 cm. in its transverse diameter. It then began to decrease in size, and this was accompanied by an improvement in the condition of the patient. The patient is living one year after operation. In Case 3, extensive fibrous adhesions between the pericardium and the heart were sectioned at operation. The pericardium was closed without drainage. Toward the end of the postoperative course, which lasted about twenty hours, the patient presented the picture of a failing circulation. A postoperative roentgenogram showed the cardiac shadow to have increased 1 cm. in its transverse diameter. At necropsy, 350 c.c. of fluid were found in the pericardial cavity, the rapid formation of which undoubtedly produced a fatal tamponade.

fatal tamponade reported in the literature. It occurs frequently following wounds of the heart and sometimes accidentally in patients that are tapped for pericardial effusion when the needle pierces a coronary vessel, a dilated auricle or even the ventricle.

The marked sensitivity of the pericardium to operative trauma, as observed in experimental work on the heart, led to a study of these sequelae with the idea that the formation of effusions and adhesions might be better understood or prevented and their serious consequences avoided.

Experiments were conducted for the purposes of observing the effects of various types of traumas common to any operative procedure. The occurrence of cardiopericardial adhesions following incision in the left ventricle, for the insertion of the cardiovalvulotome [2] to section the mitral valve, led to experiments with fat transplants into the pericardium with the idea that probably such adhesions might be prevented. The occurrence of a rapidly developing pericardial effusion following the separation of adhesions at operation (Case 3)[1] suggested that this condition might be duplicated experimentally. An attempt was made, therefore, to produce a generalized fibrous pericarditis with the idea of sectioning the adhesions later in order to determine the proper surgical treatment of the pericardium in those cases in which an effusion or tamponade might otherwise be expected to occur.

II. HISTORY

Diseases of the pericardium were noted by the early anatomists. Galen recognized pericarditis in animals and suspected the existence of the condition in man. Rondelet described the pain, dyspnea and syncope of pericarditis, and Riolan,[3] in 1649, recognized the danger of the condition and boldly suggested incision and drainage of the pericardium after trephining the sternum. Senac,[4] a hundred years later, described pericarditis and advised incision and drainage through an intercostal space to the left of the sternum. Morgagni,[5] in 1761, described the great danger of effusion into the pericardial cavity due to compression of the heart, but declared that the day was distant when the ability to recognize the condition would justify paracentesis.

2. Beck, C. S., and Cutler, E. C.: A Cardiovalvulotome, J. Exper. Med. **40**:375 (Sept.) 1924.

3. Riolan, J.: Encheiridium Anatomicum et Pathologicum Lugduni Batavorum, Ex Officina Adriani Wyngaerden, 1649, p. 206.

4. Senac: Traité de la Structure du Cœur, de son Action et de ses Maladies, Paris, **1**:2, 1749.

5. Morgagni, J. B.: De Sedibus et Causis Morborum per Anatomen Indagatis, Lovanii, E. Typographica Academica, 1756, Tomus Primus, Epist. 16.

Corvisart,[6] in 1806, referred to the uncertainty of making the correct diagnosis as prohibiting either incision or puncture of the pericardium. The precordial bulge and the increased area of percussion dulness associated with pericardial effusion, discovered by Auenbrugger and published by Corvisart [6] in 1811, were important signs in the recognition of the disease, but the difficulties besetting the diagnosis were indicated by the fact that Laënnec [7] (1819) doubted the possibility of making a correct diagnosis and, therefore, did not attempt paracentesis.

The operation of paracentesis, up to this period, was either advocated or opposed on theoretical grounds. The merit of the procedure must have received some appreciation, but two obstacles stood in the way of its performance; namely, the difficulty of making the correct diagnosis and the fear of injury to the heart, an organ that was held sacred and not to be touched. This attitude toward the heart was a heritage of the past. By Hippocrates, Aristotle, Pliny, Fallopius and others the tradition was established that all wounds of the heart were necessarily fatal, that if wounded it would never heal, being too hard, always in motion, and of an inflammatory heat. "Because the noblest organ in the body cannot survive a solution of its continuity," a patient, as recorded by Paola Zacchias in the seventeenth century, died of a needle wound of the heart. Owing to this fear only two attempts were made to drain the pericardial cavity; Desault,[8] in 1798, utilizing the method described by Senac, incised and drained an encysted pleurisy, and Larrey,[9] in 1810, performed a similar operation, but the diagnosis again was in error. According to Larrey,[10] the first wound of the pericardium to recover was one in which he inserted a catheter and evacuated from the pericardial cavity three beakers of wine colored fluid and after the passage of a sound obtained four more beakers of similar fluid.

Romero,[11] in 1819, performed the first successful pericardiotomy. He operated in three cases of pericarditis with effusion, in two of which the patients recovered. Through an incision made in the left fourth interspace near the sternum, the distended pericardium was felt with the finger, picked up with forceps and cut with scissors. Jowett,[12] in

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6. Corvisart, J. N.: Essai sur les Maladies Organiques du Cœur, Paris, 1806, p. 50; Essai sur les maladies et les lésions organiques du cœur et des gros vaisseaux, Ed. 2, Paris, 1811.

7. Laënnec: Traité de l'Auscultation Médicale et des Maladies du Poumon et du Cœur, Ed. 4, Paris, **7**:410, 1819.

8. Desault: Oeuvre Chirurgie de Desault, Paris, Bichat, **2**:304, 1798.

9. Larrey: Sur une Blessure du Péricarde Suivie d'Hydropéricarde, Bull. d. sc. méd., 1810.

10. Larrey: Clin. chir., Paris, **2**:291, 1829.

11. Romero, cited by Baizeau: Mémoire sur le Ponction du Péricarde au Point de Vue Chirurgical, Gaz. de méd. et de chir. 1868, p. 565.

12. Jowett, cited by Günther: Lehre von den Blutigen Operation am Menschlichen Körper, Leipzig, 1861, p. 102.

1827, punctured the distended pericardium with a trocar, but the fluid escaped into the thoracic cavity from which it was absorbed. With the exception of an attempt by Schuh [13] to tap the pericardial cavity in a case that proved to be a mediastinal tumor, no other cases are recorded until 1841, when an extraordinary series of successful cases was reported by Karanaeff [14] following an outbreak of scurvy in Cronstadt, Russia.

The first patient with suppurative pericarditis was operated on by Hilsmann,[15] in 1844. The pericardium was exposed and opened through an incision made in the fourth interspace. Langenbeck,[16] in 1850, similarly incised and drained in a case of purulent pericarditis.

Following a discussion of the subject by Trousseau,[17] in 1854, in which several cases of incision and drainage of the pericardium were reported, the efficacy of the procedure became more clearly recognized, although this recognition did not gain general accord. The latter is shown by statements from Billroth, who, in 1870, characterized the operation of tapping the pericardium as a surgical frivolity and a prostitution of surgical skill, and who, in 1883, declared that no surgeon who wished to preserve the respect of his colleagues would ever attempt the suture of a wound of the heart. Nevertheless, the operation thereafter was performed more frequently, and a large number of reports on the subject can be found in the literature (Roberts,[18] West,[19] Delorme and Mignon,[20] Porter,[21] and Terrier and Reymond [22]). Following the influence of Dieulafoy,[23] in 1873, aspiration of the peri-

13. Schuh and Skoda, cited by Trousseau: Arch. gén. de méd. **2**:519, 1854.

14. Karanaeff, cited by Kyber: Paracent. des Herzbeutels. Ztschr. Ruslands, Saint Petersburg, **21**:161, 1847.

15. Hilsmann, F. H.: Ueber die Paracentese des Pericardiums, Inaugural Dissertation, Kiel, 1875.

16. Langenbeck, B.: Vorlesungen über Akiurgie, August Hirschwald, Berlin, 1888.

17. Trousseau, A., and Lasegue, C.: De la Paracentèse du Péricarde, Arch. gén. de méd. **2**:513, 1854.

18. Roberts, J. B.: The Surgical Treatment of Suppurative Pericarditis, Tr. Am. Surg. A. **15**:101, 1897.

19. West, S.: A Case of Purulent Pericarditis Treated by Paracentesis and by Free Incision with Recovery; the Statistics of Paracentesis Pericardii, Tr. Med. Chir. Soc. **67**:235, 1883.

20. Delorme and Mignon: Sur la Ponction et l'Incision du Péricarde, Rev. de chir. **15**:797, 1895.

21. Porter, C. B.: Suppurative Pericarditis and Its Surgical Treatment with an Analysis of Fifty-one Cases Reported in the Literature, Ann. Surg. **32**:769, 1900.

22. Terrier, F., and Reymond, E.: Chirurgie du Cœur et du Péricarde, Paris Ancienne Libraire Germer Bailliere et Cie, 1898.

23. Dieulafoy, G.: A Treatise on the Pneumatic Aspiration of Morbid Fluids, Philadelphia, J. B. Lippincott Company, 1873.

cardium supplanted the method of open incision and drainage, and since that time this method of treating cases of serous effusion became the one of common practice.

A most important advance in the surgery of the pericardium, however, lay in a better recognition of the pathologic physiology of increased pressure in the pericardial cavity. Its importance, although suggested by Morgagni,[4] in 1761, had received but little attention until the excellent presentation of "herz tamponade" by Rose,[24] in 1884, and the physiologic experiments by Cohnheim,[25] in 1889. This work afforded a physiologic basis for the treatment of pericardial effusion and emphasized the clinical importance of tamponade following wounds of the heart.

The first experiments in the suture of wounds of the heart were performed by Bloch [26] on rabbits, in 1882. This work aroused little interest until the Eleventh International Medical Congress at Rome, in 1895, when Del Vecchio [27] demonstrated in dogs healed wounds of the heart following suture. Almost within a year from this date, three attempts to suture wounds of the human heart were made, the first by Cappelen [28] of Christiania, the second by Farina [29] of Rome, and the third by Rehn [30] of Frankfurt, the last of which was successful. The importance of this advance is indicated by the remarkable decrease in the percentage of fatal wounds of the heart. Of the 305 cases that had been treated by suture, compiled by Tuffier,[31] in 1920, 50.4 per cent. of the patients recovered; whereas of the 452 cases compiled by Fischer,[32] in 1868, all except seventy-two were fatal. In the latter series of cases, the fatal termination was commonly due to hemopericardium, the "herz tamponade" of Rose.

Such was the status of the surgery of the pericardium and the heart at the beginning of the twentieth century. The pericardial cavity was incised or aspirated for pericardial effusions, serous, hemorrhagic

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24. Rose, E.: Herz tamponade (Ein Beitrag zur Herzchirurgie), Deutsch. Ztschr. f. Chir. **20**:329, 1884.

25. Cohnheim, J.: Lectures on General Pathology, New Sydenham Soc., **1**:21, 1889.

26. Bloch, M. H.: Discussion, Verhandl. d. deutsch. Gesellsch. f. Chir., Eleventh Congress, Berlin, 1882, Part 1, p. 108.

27. Del Vecchio: Sutura del Cuore, Riforma med. **2**:38, 1895.

28. Cappelen, A.: Vulnia Cordis, Sutur af Hjertet, Norsk Mag. f. Laegevidensk. **11**:285, 1896.

29. Farina: Discussion, Centralbl. f. Chir. **23**:1224, 1896.

30. Rehn, L.: Ueber Penetrierende Herzwunden und Herznaht, Arch. f. klin Chir. **55**:315, 1897.

31. Tuffier, T.: La Chirurgie du Cœur, Cinquieme Congrès de la Soc. Int. de Chirurgie, Paris, July 19-23, 1920, Brussels, M. Hayez, 1921.

32. Fischer, G.: Die Wunden des Herzens, Arch. f. klin. Chir. **9**:571, 1868.

and purulent; foreign bodies were removed from the pericardium; tamponade was relieved by the removal of blood clots, and wounds of the heart were sutured. As a further advance in the surgery of the pericardium, the Brauer [33] operation of cardiolysis is mentioned as being attended in general with good results. The section of cardiopericardial adhesions, however, as suggested by Delorme,[34] has not gained favor because of the great tendency for the reformation of the adhesions. The treatment of tuberculous pericarditis by the production of a pneumopericardium with air, nitrogen or oxygen has been carried out in a few cases, according to Wenckeback,[35] Emile-Weil,[36] Meyer,[37] Castex,[38] Salmond [39] and Oppenheimer.[40] Nothing that is definite can be stated concerning the beneficial results of such treatment beyond the removal of the fluid, except that in one case an encysted pocket of fluid was demonstrated in the pericardial sac by the roentgenograph and was aspirated.

At present, the subject of relieving by surgical procedures the mechanical obstruction within the heart is receiving consideration, and four attempts to section the stenosed mitral valve in human cases have been carried out. It was in conjunction with these cases and the associated experimental work that this study of the pericardium in relation to the surgery of the heart was undertaken.

III. EXPERIMENTS AND COMMENT

The operative procedure for the exposure of the pericardium was the same in all experiments. The dog, after having received morphin, was anesthetized with ether administered by a cone. When the animal

33. Brauer, L.: Ueber Chronische Adhäsive Mediastino Pericarditis und deren Behandlung, München. med. Wchnschr. **49**:1072, 1902; Die Kardiolysis und ihre Indicationen, Arch. f. klin. Chir. **71**:258, 1903.

34. Delorme, E.: Sur un Traitement Chirurgical de la Symphyse Cardo-Péricardique, Gaz. d. hôp. 1898, No. 125, p. 1150; De la Légitimité et de l'Opportunité de la Destruction des Adhérences Cardo-Péricardiques, ibid. **86**:2269, 1913.

35. Wenckeback, K. F.: Beobachtungen bei Exsudativer und Adhäsiver Perikarditis, Ztschr. f. klin. Med. **71**:402, 1910.

36. Emile-Weil, P., and Loiseleur: Contribution à l'Étude de la Péricardite Tuberculeuse; Insufflation d'Air dans le Pericarde; Pneumopéricarde et Hydropneumopéricarde Artificiels, Bull. et mém. Soc. méd. d. hôp. de Paris **40**:1715, 1916.

37. Meyer, W.: A Case of Artificial Pneumocardium, Med. Rec. **93**:38 (Feb. 2) 1918.

38. Castex, M. R.: La Pneumopéricarde Therapeutique, Bull. et mém. Soc. méd. de hôp. de Paris **47**:545 (April 13) 1923.

39. Salmond, R. W. A.: Artificial Pneumopericardium, Arch. Radiol. & Electroth. **28**:20 (June) 1923.

40. Oppenheimer, R. H.: Therapeutic Pneumocardium in Pericarditis with Effusion, J. A. M. A. **82**:1685 (May 24) 1924.

was fully relaxed, a properly fitting rubber tube was inserted into the trachea through the larynx. Mechanical respiration was provided admirably by the Erlanger apparatus, by means of which air mixed with varying amounts of ether vapor was forced intermittently under slight pressure into the trachea. The exhaled air escaped through the space between the intratracheal tube and the trachea, and, to obtain the proper degree of aeration of the lungs, it was most important that the tube be neither too large nor too small in relation to the trachea. The dog was placed on the right side with the forelegs extended. The thorax was shaved, and the skin was cleansed with soap, water, ether and alcohol. The sterile drapings were carefully placed, and a rigid aseptic technic was observed. An incision, made directly over and parallel to the fifth rib, was carried through skin, platysma, latissimus dorsi and, sometimes, a small part of the external oblique and pectoralis minor muscles to the periosteum of the rib. The fifth rib was removed subperiosteally from its costochondral articulation laterally about 4 inches (10.1 cm.). The pleura was incised, and the margins of the wound were retracted. As the chest was opened, it was necessary sometimes to regulate the degree of aeration of the lungs. The lungs were protected by two or three thin pads of cotton moistened with physiologic sodium chlorid solution at a temperature of 105 F., and the pericardium was exposed. The further procedure depended on the nature of the experiment, and is given in the protocols. Before the pleura was completely closed, the lungs were expanded to expel the air from the chest, and the wound was sutured with silk in layers.

Roentgen-ray studies were made before operation and at frequent intervals thereafter to see what data might be obtained concerning the size and the shape of the cardiac shadow. The roentgen-ray tube and the screen were placed at fixed distances from the heart, the former being placed at a distance of 5 feet from the screen, and the latter touching the dog. By this method, direct comparisons of the cardiac shadows were possible.[41] The delicate mediastinum in the dog permits easy rotation of the heart, which, in turn, may alter the size and the shape of the cardiac shadow. To avoid rotation of the heart as much as possible, the dog was placed on the table in the direct anteroposterior position, and even when this was carried out carefully there was in repeated roentgen-ray shadows a light margin of error. All measure-

41. A table was built which made it possible to take four roentgenograms on one plate, 11 by 14 inches. A large sheet of lead was bent to conform to the shape of the dog, and in it was cut a window, 5½ by 7 inches, so that the heart lay in a direct line from the window to the roentgen-ray target. A tray to contain the screen was built beneath the window so that the screen when shifted to the four cardinal positions would have all its surface exposed without overlapping and without waste of the film.

ments of the cardiac shadows given below represent the greatest transverse diameter in centimeters with the dog in the anteroposterior position.

1. THE EFFECT OF MECHANICAL TRAUMA APPLIED TO THE PERICARDIUM

EXPERIMENT 1.—A white and brown, male collie was operated on, Jan. 15, 1924; the pericardium was incised about 3 inches (7.6 cm.), and the heart was exposed. The epicardium and the parietal pericardium were rubbed gently with a gauze sponge for a period of five or ten minutes. The pericardium was sutured

Fig. 1.—Cardiopericardial adhesions following trauma produced by gentle rubbing of the visceral and parietal pericardium.

with silk. In the roentgenograms, the transverse diameter of the preoperative cardiac shadow was 7.2 cm.; immediately after operation, it was 7.3 cm.; seven hours after, 7.9 cm.; one day, 7.8 cm.; two days, 7.5 cm.; three days, 7.5 cm., and fifteen days, 7.2 cm. The dog was in apparent good health throughout the postoperative period. He was killed eighty-seven days after the operation. The lung was adherent to the pericardium at the suture line. The pericardium was intimately adherent to almost the entire surface of the heart (Fig. 1). The pericardial fluid was entirely absent.

EXPERIMENT 2.—A fox terrier, weighing 7.4 kg., was operated on, May 12, 1924; the epicardium and the parietal pericardium were rubbed gently with a gauze sponge throughout their entire extent. The pericardium was closed with a continuous silk suture. There was a normal convalescence. The dog was killed ten days after the operation. The lung was adherent to the pericardium at the suture line. The pericardium was adherent to the heart everywhere except over an area of about 4 sq. cm. on the right ventricle. The adhesions were thin, fibrous and easily separated, except at the suture line of the pericardium where the adhesions were very firm. There was no pericardial fluid.

EXPERIMENT 3.—A brown and white, female mongrel, weighing 18 kg., was operated on, April 2, 1924; the outer surface of the pericardium on the left side was slapped with a metal spatula to the extent of producing very small petechiae, and the heart was vigorously massaged with the gloved hand. The pericardium was not opened. The dog was in good health throughout the postoperative period. In the roentgenograms, the transverse diameter of the cardiac shadow immediately after operation was 7.7 cm.; five days after, 7.8 cm.; thirteen days, 7.9 cm.; nineteen days, 8 cm., and thirty-seven days, 8.2 cm. The dog was killed fifty-four days after the operation. The lung was not adherent to the scar in the chest but was adherent to the pericardium where the latter had been traumatized at operation. The pericardial fluid was normal. There were no cardiopericardial adhesions.

EXPERIMENT 4.—A brown and white, male setter, weighing 23.5 kg., was operated on, April 16, 1924, the same procedure being carried out as in Experiment 3. The pericardium was not opened. The dog was in good health during the postoperative period. In the roentgenograms, the cardiac shadow had a diameter of 8.2 cm. before operation; immediately after operation, 8.5 cm.; nine days after, 8.5 cm., and twenty-three days, 8.8 cm. The dog was killed forty-two days after the operation. The left lung was adherent to the pericardium where the latter had been traumatized at operation. There was a very small amount of clear pericardial fluid. There were no cardiopericardial adhesions.

EXPERIMENT 5.—A brown and white, female mongrel, weighing 19 kg., was operated on, April 16, 1924, the same procedure being used as in Experiment 3. The dog, which was in good health during the postoperative period, was killed forty-seven days after the operation. The lung was not adherent to the scar in the chest. There was a small adherent area between the left lung and the pericardium where the latter had been traumatized. There were no cardiopericardial adhesions. The pericardial fluid was normal.

EXPERIMENT 6.—A black and white, male hound, weighing 10.2 kg., was operated on, April 17, 1924, by the same procedure as that used in Experiment 3. The dog was in good health during the postoperative period. In the roentgenograms, the cardiac shadow before operation was 6 cm.; immediately after operation, 6 cm.; four days after, 6.6 cm.; six days after, 6.7 cm., and twenty-two days, 6.9 cm. The dog was killed forty-six days after operation. The lung was not adherent to the scar in the left chest. There was a small adhesion between the lung and the pericardium where the latter had been traumatized at operation. There were no cardiopericardial adhesions. The pericardial fluid was normal.

The foregoing experiments indicate that cardiopericardial adhesions are formed following trauma applied directly to the visceral and parietal pericardium, such as that produced by sponging with gauze. The fact

that intrapericardial adhesions did not follow trauma applied to the outer surface of the pericardium indicates that the formation of such adhesions depends on direct injury to its endothelial surface. In Experiment 1, the postoperative increase in the transverse diameter of the cardiac shadow, with the subsequent return to the preoperative size, probably indicated the formation of a pericardial effusion which subsequently was entirely absorbed. This probable explanation of the increase in size of the cardiac shadow does not apply to Experiments 3, 4 and 6, in which the increase in size was gradual but constant, and in which the pericardial fluid at necropsy was not increased in amount.

The marked sensitivity of the heart and the pericardium to the formation of adhesions following trauma was shown further in a series of experiments conducted in this laboratory for the purpose of cutting the mitral valve, using either a small knife on a long slender shaft or the cardiovalvulotome.[2] In those experiments with the knife in which an incision about 3 mm. long was made in the ventricle, usually necessitating one suture to control hemorrhage, an adhesion between the wound and the pericardium formed in about three-fourths of the cases. In the experiments with the cardiovalvulotome in which an incision about 1 cm. long was made in the ventricle, usually necessitating two sutures to control hemorrhage, a firm adhesion between the wound and the pericardium formed in about nine tenths of the cases. In about one third of the latter experiments, a few very delicate adhesions to the pericardium formed elsewhere on the surface of the heart, usually at the ear of the left auricle, which had been invaginated into the mitral ring by the gloved finger in feeling the end of the valvulotone for its orientation at operation. In about one-half the cases, the lung became adherent to the pericardium where the latter had been sutured, and these adhesions, as they did not displace the pericardium and the heart from the normal position, were not indicated on the roentgen-ray shadows.

2. THE EFFECT OF BLOOD IN THE PERICARDIAL CAVITY

EXPERIMENT 7.—A large, brown collie was operated on, May 2, 1924; an effort was made to aspirate blood from the intrapericardial portion of the aorta. As the needle was withdrawn, bleeding into the pericardial cavity occurred, producing a dark discoloration, as seen through the pericardium. In the roentgenograms, the transverse diameter of the cardiac shadow before operation was 7.4 cm.; immediately after operation, 8.3 cm., and seven days after, 7.5 cm. The dog, which was healthy throughout the postoperative period, was killed eighteen days after the operation. The left lung was adherent to the chest wound and not adherent to the pericardium. No trace of the blood was found in the pericardial cavity, and there were no intrapericardial adhesions. The serous lining of the pericardial cavity was everywhere smooth, glistening and of normal appearance.

EXPERIMENT 8.—A collie was operated on, May 2, 1924; 1 c.c. of blood taken from the femoral vein was injected into the pericardial cavity. In the

roentgenograms, the transverse diameter of the cardiac shadow before operation was 7.8 cm.; immediately after operation, 7.8 cm.; three days after, 7.3 cm., and seven days, 7.3 cm. The dog, which had a normal postoperative course, was killed seventeen days after the operation. There was a small adhesion between the lung and the chest wound. No trace of the blood was found in the pericardial cavity. There were no intrapericardial adhesions. The serous surfaces were normal throughout.

Blood in the pericardial cavity per se is of no consequence in the formation of adhesions. It is absorbed in a few days, leaving the pericardial fluid clear and producing no pathologic changes in the serous surfaces of the heart and the pericardium. These results agree with those obtained by Rehn,[42] who performed similar experiments on dogs.

3. THE EFFECT OF HOT SOLUTION APPLIED TO THE HEART AND TO THE PERICARDIUM

EXPERIMENT 9.—A female terrier, weighing 8 kg., was operated on, Jan. 16, 1924; a small, soft rubber catheter was inserted through a short incision in the pericardium to the posterior aspect of the heart, and 150 c.c. of physiologic sodium chlorid solution at a temperature of 65 C. was introduced. The temperature of the fluid in the pericardium was thus raised to 45 C. The incision in the pericardium was sutured. In the roentgenograms, the transverse diameter of the cardiac shadow before operation was 7 cm.; immediately after operation, 6.6 cm.; two days after, 7.7 cm.; five days, 7.5 cm., and 100 days, 7.5 cm. Throughout the postoperative period, the dog was in apparent good health. She was killed 104 days after the operation. The lung was adherent to the pericardium and to the scar in the chest. The pericardium was everywhere intimately adherent to the heart (Fig. 2). Pericardial fluid was absent.

The effect of hot salt solution applied directly to the heart and to the pericardium had been demonstrated repeatedly in experiments in which it was used to stimulate the heart after creating a mitral regurgitation. In those experiments, extensive generalized adhesions were formed, intimately uniting the heart and the pericardium. After the sensitivity of these structures was better appreciated, salt solution at a temperature above 105 F. was not used, and the result was that intrapericardial adhesions became less frequent and less generalized, being confined chiefly to the operative scar in the heart.

4. THE EFFECT OF INFECTION IN THE PERICARDIAL CAVITY

EXPERIMENT 10.—A male collie, weighing 20 kg., was operated on, April 22, 1924; one-half cubic centimeter of a 24 hour broth culture, Type I pneumococcus, was injected into the pericardial cavity. The small puncture wound in the pericardium was touched with a cotton pledget moistened with alcohol to prevent infection of the pleura. The dog was in good health during the postoperative period. In the roentgenograms, the transverse diameter of the cardiac shadow before operation was 8.2 cm.; immediately after operation, 8.2 cm.;

42. Rehn, L.: Zur Experimentellen Pathologie des Herzbeutels, Verhandl. d. deutsch. Gesellsch. f. Chir., 1913, p. 339.

one day after, 8.2 cm.; three days, 7.9 cm.; seventeen days, 7.8 cm., and forty-one days, 7.6 cm. The dog was killed forty-two days after the operation. There were no adhesions between the scar in the chest and the lung. The lung was adherent to the pericardium at the point where the hypodermic needle was inserted. A fibrous adhesion about 1 cm. long and 5 mm. in diameter connected this area to the underlying surface of the heart where it spread out to about 4 sq. cm.. Over a few square centimeters of the surface of the right ventricle was a thin film of fibrin adherent to the epicardium. The pericardial fluid was clear and free from infection.

EXPERIMENT 11.—A male hound, weighing 11.8 kg., was operated on, April 22, 1924; 1 c.c. of the same culture as that used in Experiment 10 was injected

Fig. 2.—Cardiopericardial adhesions following application of hot salt solution.

into the pericardial cavity. The point of puncture of the pericardium was touched with a cotton pledget moistened with alcohol. The postoperative condition apparently was good. In the roentgenograms, the transverse diameter of the cardiac shadow before operation was 6.3 cm.; one day after operation, 6.2 cm.; two days, 6.5 cm.; three days, 6.4 cm.; seventeen days, 6.9 cm., and forty-one days, 7 cm. The dog was killed forty-two days after the operation. The lung was adherent to the scar in the chest, and also to the pericardium. There were no intrapericardial adhesions. The pericardial fluid was clear, not infected and of normal amount.

EXPERIMENT 12.—A male airedale, weighing 8.2 kg., was operated on, May 7, 1924; 1 c.c. of a saline suspension of pneumococci grown from a case of empyema was injected into the pericardial cavity. The pericardium was touched

with a cotton pledget moistened with alcohol at the point where the injection was made. The postoperative period was uneventful. In the roentgenograms, the transverse diameter of the cardiac shadow before operation was 6.7 cm.; immediately after operation, 6.7 cm.; two days after, 7 cm.; twenty-six days, 6.2 cm. The dog was killed twenty-six days after the operation. The lung was adherent to the scar in the chest and to the pericardium at the point where the injection had been made and touched with alcohol. The pericardial fluid was clear. There were no pericardial adhesions. The surface of the heart and the pericardium was everywhere glistening.

EXPERIMENT 13.—A female mongrel, weighing 14.2 kg., was operated on April 29, 1924; 1 c.c. of a 24 hour broth culture of nonhemolytic streptococcus was injected into the pericardial cavity, and the pericardium at the point of injection was touched with alcohol. In the roentgenograms, the cardiac shadow before operation was 7.4 cm.; immediately after operation, 7.4 cm., and one day after, 7.6 cm. Death followed twenty-four hours after the operation. There was about 10 c.c. of turbid fluid stained with blood in each pleural cavity. The lungs showed a generalized consolidation. There was about 20 c.c. of blood stained fluid in the pericardial cavity. The surface of the heart was studded with petechial hemorrhages. There were no adhesions.

EXPERIMENT 14.—A male mongrel, weighing 14 kg., was operated on, April 30, 1924; 1 c.c. of a broth culture nonhemolytic streptococcus was injected into the pericardial cavity, and the pericardium at the point of injection was touched with alcohol. In the roentgenograms, the cardiac shadow before operation was 7.6 cm.; postoperative, 7.6 cm.; one day postoperative, 9.2 cm. The dog died two days after the operation. There was about 25 c.c. of bloody fluid in each chest. The lungs were consolidated. About 120 c.c. of dark, blood stained fluid was contained in the pericardial cavity. There were no adhesions. The surface of the heart was discolored and contained numerous petechial spots. There was no fluid in the abdomen.

EXPERIMENT 15.—A female mongrel, weighing 9 kg., was operated on, May 1, 1924; 2 minims of a streptococcus culture were injected as in Experiment 13. In the roentgenogram the transverse diameter of the cardiac shadow before operation was 6.7 cm.; immediately after operation, 6.6 cm.; one day after, 6.6 cm.; two days, 6.7 cm.; four days, 6.6 cm., and thirty-two days, 6.4 cm. The dog was in apparent good health following the operation, and was killed thirty-three days after the operation. The lung was adherent to the scar in the chest and also to the pericardium. The lungs were negative. There was no fluid in the chest. There was one firm adhesion about 8 mm. in diameter between the heart and the pericardium at the point where the injection was made. The epicardium was of normal appearance.

EXPERIMENT 16.—A female mongrel, weighing 12 kg., was operated on, May 7, 1924; 1 c.c. of *Staphylococcus aureus* broth culture was injected into the pericardial cavity. The pericardium at the point of injection was touched with alcohol. In the roentgenograms, the diameter of the cardiac shadow before operation was 6.8 cm.; immediately after operation, 6.7 cm., and two days after, 7.4 cm. The dog died four days after operation. There was about 100 c.c. of blood stained purulent fluid in each chest. The pericardial cavity contained 20 c.c. of purulent fluid. There were no adhesions and no consolidation of the lungs was present.

The anatomic arrangement of the mediastinum in the dog makes it difficult to approach the pericardium without opening the pleural cavity, and because of the great sensitivity of the pleura to infection this complicating factor is introduced into these experiments.

In two of the three experiments in which Type I pneumococcus was used, no signs of infection were found subsequently, either in the pericardium or in the pleura. The adhesion between the lung and the pericardium that formed in each case was due probably to the irritation produced at operation by touching the pericardium at the point of injection with a cotton pledget moistened with alcohol. The third dog survived the infection but showed a fibrous adhesion between the pericardium and the heart and a thin film of fibrin over part of the right ventricle which may have been produced by the infection.

A culture of nonhemolytic streptococcus was injected into the pericardial cavity of three dogs. The dogs that received 1 c.c. of the culture died within two days following the injection from pericarditis with effusion and from empyema. The third dog received 2 minims of the culture, survived the infection and was in good condition when killed thirty-three days later. One firm adhesion between the heart and the pericardium was found.

The injection of a culture of *Staphylococcus aureus* into the pericardial cavity of one dog was fatal in four days, the dog dying from purulent pericarditis and empyema.

Of forty-six dogs that survived an attempt to section the normal mitral valve, five died from either empyema or pericarditis with effusion. One of these had pericarditis with a purulent effusion but without any gross signs of infection in the pleura. The remaining four had empyema, two of which had no gross signs of infection in the pericardial cavity.

The foregoing data indicate that the tolerance of the pericardial cavity to infection is similar to that of the pleural cavity and should be accorded the same rigid aseptic technic as is demanded by any intrapleural operation.

5. THE EFFECT OF TINCTURE OF IODIN INJECTED INTO THE PERICARDIAL CAVITY

EXPERIMENT 17.—A female collie, weighing 10.9 kg., was operated on, May 15, 1924; 3 c.c. of 10 per cent. tincture of iodin was injected into the pericardial cavity. In the roentgenograms, the transverse diameter of the cardiac shadow before operation was 6.5 cm.; two days after operation, 6.9 cm.; four days after, 7.2 cm., and fourteen days, 7.5 cm. The dog lost 1 kg. of weight during the postoperative course, and died nineteen days after the operation. The right pleural cavity contained 400 c.c. of slightly turbid, yellow fluid. The left pleural cavity contained 250 c.c. of similar fluid. The pericardium was thickened, friable and hemorrhagic, and was intimately united everywhere to the heart by many elastic adhesions which were easily broken.

The pericardial cavity contained 90 c.c. of hemorrhagic fluid. The abdominal cavity contained 110 c.c. of serous fluid. A fibrinous layer of exudate united the opposing surfaces of the various lobes of the liver. The lungs and the liver were congested.

Chemical irritants were injected into the pericardial cavity with the idea of producing a marked fibrous pericarditis. It was hoped that the adhesions could be divided subsequently and that studies could be made of the proper disposition of the pericardium in such cases, but this end was not accomplished.

Fig. 3.—Cardiopericardial adhesions following injection of tincture of iodin into pericardial cavity; the pericardium was friable and broke into pieces as it was separated from the heart.

Ten per cent. tincture of iodin was injected into the pericardial cavity of seven dogs in amounts varying from one-half to 4 c.c. The injection of the larger amounts of iodin was followed by generalized toxic effects characterized by a marked pericarditis with hemorrhagic effusion (Fig. 3); a serous effusion into the chest and abdomen; a fibrinous exudate over the lobes of the liver, and death usually within a month. In the experiments in which smaller amounts of iodin were used, the effect was chiefly a pericarditis with hemorrhagic effusion (Fig. 4), the adhesions being delicate and easily broken. It is probable

that firm, generalized adhesions would develop in such cases after several months, but the desirability of using a chemical irritant that does not possess such generalized toxic effects is apparent.

Ether was injected into the pericardial cavity in one experiment and the dog when killed seven days later presented a picture similar to that following the injection of large amounts of tincture of iodin, namely, a marked pericarditis with hemorrhagic effusion into the pericardium, chest and abdomen, and a thick layer of fibrinous exudate between the lobes of the liver (Fig. 5).

6. THE TRANSPLANTATION OF FAT INTO DEFECTS OF THE PERICARDIUM

EXPERIMENT 18.—A female collie, weighing 27.6 kg., was operated on, May 16, 1924; the pericardium was incised, and the heart was exposed. A procedure was carried out similar to that utilized in inserting the cardiovalvulotome into

Fig. 4.—Cardiac shadows showing effusion following injection of one-half cubic centimeter of tincture of iodin into pericardial cavity; *A*, before injection; *B*, three days after injection, and *C*, eight days after injection; 35 c.c. of hemorrhagic fluid were found at necropsy.

the heart to section the mitral valve. After two control sutures had been placed, an incision about 1 cm. long was made in the left ventricle. The incision was then closed with two Lembert sutures of silk, and the control sutures were removed. There was no bleeding. A piece of the pericardium, about 9 sq. cm. in area and overlying the sutured wound in the ventricle, was excised, and this defect was replaced by a transplant of fat. The fat used for the transplant was taken from the outer surface of the pericardium and was cut to fit the defect in the pericardium. It was then sutured in place with fine silk. The dog was in good health, and was killed eighteen days after the operation. The lung was adherent to the lower corner of the transplant. The outer surface of the transplant was glistening and showed a fine tracery of blood vessels. On the inner surface, the transplant was intimately adherent throughout its entire extent, and the adhesion was very strong directly over the healed scar in the heart (Fig. 6).

The frequent formation of firm adhesions between the pericardium and the heart, following incision of the latter in those experiments in which the cardiovalvulotome was used, has been mentioned. Transplants of fat were sutured into the pericardium in three dogs so that the incision in the ventricle came into contact with the transplant. In each case, the transplant became intimately adherent to the healed wound in the heart (Fig. 6), and the adhesion was no less firm nor less extensive than in similar cases without the transplantation of fat. Klose [43] sutured transplants of fat, fascia and peritoneum into defects

Fig. 5.—Pericarditis seven days after injection of 10 c.c. of ether into pericardial cavity.

of the pericardium and found that adhesions did not form between the transplants of fat and the heart. In those experiments, however, an incision was not made in the heart.

7. HEART TAMPONADE

The term "heart tamponade," as has been stated, was coined by Rose,[24] in 1884, but the danger of pericardial effusion was recognized earlier by Morgagni.[4] Experiments, first by Cohnheim [25] and later by many others, have shown that an increased pressure in the pericardial cavity is accompanied by a fall in the arterial pressure and a rise in

43. Klose, H.: Die Reine Synechie und der Plastische Ersatz des Herzbeutels, Arch. f. klin. Chir. **117**:138, 1921.

the venous pressure, and that these phenomena are brought about by the obstruction to the filling of the heart produced by the increased intrapericardial pressure. When this reaches the level of the venous pressure, the heart, as shown by Kuno,[44] ceases to function. Such pressure curves are shown in Figure 7.

Fig. 6.—A transplant of fat had been placed in the pericardium overlying a sutured wound in the left ventricle; a firm adhesion formed between the heart and the transplant.

This physiologic principle gains frequent clinical expression. Pericardial effusions, especially those that are formed rapidly so that the

44. Kuno, Yas: The Mechanical Effect of Fluid in the Pericardium on the Function of the Heart, J. Physiol. **51**:221 (Sept.) 1917.

pericardium does not accommodate itself by dilatation, obstruct the filling and, therefore, the output of the heart. The principle is strikingly expressed in cases of stab wounds in which blood fills the pericardial cavity, and may quickly lead to a fatal termination. The following case reports [45] illustrate the condition.

Fig. 7.—Curves showing the effect of tamponade on arterial and venous pressures; upper: femoral artery; middle: innominate vein; lower: changes in intrapericardial pressure. The cannulas were attached to Marey tambours; as the intrapericardial pressure was increased, the arterial pressure decreased, and the venous pressure increased. The increase in the intrapericardial pressure was a column of water 10 cm. in height; the time is shown in seconds.

REPORT OF CASES

CASE 1.—A colored boy, aged 13 years, was admitted to the New Haven Hospital, June 29, 1923, presenting the general picture of collapse, with a stab wound in the fourth left interspace 2½ inches (6.2 cm.) from the midsternal line. The

45. We are indebted to Dr. S. C. Harvey, professor of surgery, Yale University School of Medicine, for permission to report Case 1.

stab wound at the skin was about 1 inch (2.5 cm.) long and was neither bleeding nor sucking air. The patient was semiconscious; the mucous membranes were blanched; the skin was cool and moist. The radial pulse was imperceptible; the systolic blood pressure was from 40 to 50 mm. The heart sounds were faintly heard over the precordium. The area of cardiac dulness was increased. The diagnosis of hemopericardium was made, and an immediate operation, under ether anesthesia, was performed by Dr. S. C. Harvey.

The skin incision extended over the midsternum from the level of the second rib to slightly below the ensiform cartilage. The diaphragmatic attachment posterior to the ensiform was freed with the finger, and the pericardium was separated from the sternum. The sternum was split with bone cutting forceps from the ensiform to the level of the third rib, and then laterally to the sternal margins. The sternum was retracted, and an ample exposure of the pericardium was obtained. The pericardium was found to be distended. It was opened in the midline from the base to the apex. As it was opened, a blood clot emerged and, approximately, from 200 to 300 c.c. of dark clotted blood, apparently venous, was evacuated from the pericardial cavity. There was no active bleeding. When the pericardium was opened, the force of the heart beat became stronger, and the radial pulse became perceptible. A most careful examination of the heart did not reveal any wound. The heart was easily displaced from the pericardial cavity, and inspection of its posterior surface and the roots of the great vessels was possible. During the manipulation, the blood pressure rose to 90 mm., and the pulse rate varied from 90 to 98 a minute. No definite wound of the heart could be found, although it is probable that the wound may have been sealed with a clot. A small rubber tissue drain was placed in the pericardium, which was closed by interrupted silk sutures. Similarly, silk sutures in the periosteum and adjacent soft parts approximated the sternum. The stab wound was excised, and the skin margins were sutured.

A half hour after the operation was completed, profuse bleeding occurred from the stab wound. The bleeding was stopped by pressure, but recurred several times so that about 300 c.c. of blood was lost. The stab wound was opened wider and explored. A little blood was seen in the left chest, but there was no active bleeding from either the internal mammary or the intercostal artery. A few sutures were removed from the pericardium, but no bleeding was found. The skin was sutured.

The patient made a good recovery. The temperature varied from 100 to 101 during the first five days; it was normal on the seventh day, at which point it remained. The respiratory rate increased to 30 or 40 during the first three days, and then gradually decreased to normal with the disappearance of the pneumothorax. The wounds healed by first intention. On the tenth day, a pericardial friction rub was noted 1 cm. lateral to the left nipple, and there was slight dulness to percussion at the left base. On the sixteenth day, the patient was up in a chair. The roentgen-ray examination, at this time, showed a slight cloudiness at the left base. The patient was discharged from the hospital twenty-three days after the operation, at which time the pericardial friction rub had disappeared and the heart sounds were normal. The dulness at the left base had disappeared. The sternum united with no deformity of the chest. The general condition was excellent.

CASE 2.—A man, aged 26, was admitted to the Peter Bent Brigham Hospital, Feb. 9, 1924, presenting the signs of extreme cardiac decompensation with mitral stenosis. The presence of a pericardial effusion was suspected. A small

lumbar puncture needle was inserted just below and to the right of the ensiform cartilage, and directed sharply upward. Pulsations of the heart were transmitted through the needle, and blood was obtained. It was thought that the needle had entered the cavity of the heart, and it was partly withdrawn. No pericardial fluid was obtained. Death occurred one hour after the tapping.

Fig. 8.—Human heart showing a puncture wound of the right ventricle involving a coronary vessel, occurring as an accident of pericardial tapping performed with a needle. Death occurred from heart tamponade one hour after the tapping.

At necropsy, 500 c.c. of thick red blood was obtained from the pericardial cavity. A puncture wound was found on the anterior surface of the right ventricle near a small radicle of the anterior ventricular branch of the right coronary artery (Fig. 8). Through the puncture wound a small probe could

be passed into the cavity of the heart. The immediate terminus was due, apparently, to heart tamponade. The bleeding occurred from the coronary vessel rather than from the right ventricle, the size of the puncture making the latter improbable.

The rapidity with which the pericardial fluid forms is an important factor in the outcome of the case. In experiments on dogs, the injection of 150 c.c. of fluid into the pericardial cavity over a period of thirty minutes was fatal. In clinical cases, however, in which the formation of the effusion takes place gradually, as much as from 2 to 4 liters of fluid may collect in the pericardial cavity, as was reported in cases of scurvy in Russia. In these cases, the pericardium dilates, and, as its limit of elasticity is approached, the intrapericardial pressure rises, and, when it equals the pressure in the venae cavae, blood no longer enters the heart, and the condition becomes fatal. The following experiment illustrates the condition:

EXPERIMENT 19.—A male mongrel terrier, weighing 20 kg., was operated on, Feb. 14, 1924, the usual exposure of the heart being made. Twelve radium seeds of 1½ millicuries each were inserted into the mitral ring with the purpose of producing stenosis of the mitral valve. In the roentgenograms, the transverse diameter of the cardiac shadow before operation was 7.8 cm.; immediately after operation, 7.9 cm.; six days after, 8 cm.; fifteen days, 8.6 cm.; twenty-five days, 10.2 cm., and twenty-seven days, 10.5 cm. During this period, there was no murmur. With the enlargement of the cardiac shadow, the pulse and respirations became rapid, and, on the twenty-seventh day, the dog fell over dead. The pericardium was greatly distended and contained 400 c.c. of blood, part of which was in the form of old clots. The heart itself was small and seemed to have been compressed. Owing to the action of the radium, an area of softening was produced at the base of the left ventricle involving a coronary vein from which blood had escaped into the pericardial cavity. As seen from the roentgen-ray shadows, the bleeding had occurred over a period of about two weeks.

The early advocates of paracentesis of the pericardium, because of their regard for the danger of injury to the heart, exposed the pericardium to view before incising or puncturing it. At present, when pericardial tapping is done blindly with a needle, accidents following injury to the heart may occur, and, indeed, furnish a strong argument for the open operative method. Furthermore, the experience gained in cardiac surgery on dogs, the persistent bleeding encountered in piercing a coronary vessel with a needle, or in making a rent in the auricle or ventricle, leads one to feel that the method of paracentesis by a needle should be replaced by the safer method of exposing the pericardium to view before incising or puncturing it. As stated by Sir Charles Ballance:[46]

46. Ballance, C. A.: The Surgery of the Heart, Bradshaw Lecture, 1919, New York, Macmillan Company, 1920.

The operation of aspiration of the pericardium should be banished from surgical practice; just as puncture of the distended intestine is no longer done in cases of obstruction. It is a leap in the dark, and many cases of wound of the heart or coronary artery have occurred in the course of this operation. Free and safe exposure of the pericardium can be obtained by removing the sternal ends of the left sixth and seventh cartilages. The pulp of the surgeon's finger must be able to examine the pericardium before an incision is made. The knife should be employed to open the pericardial sac. The abundant literature that has accumulated, and the diversity of opinion as to the best site for puncture, is of itself evidence that paracentesis is neither simple nor safe.

8. THE EFFECT OF PERICARDIECTOMY

The occurrence of adhesions and the possibility of tamponade introduced the question whether these sequelae could be avoided by resection of the pericardium. The necessity of the pericardium for the normal function of the heart was, therefore, investigated. The advisability of resecting the pericardium has been suggested also in cases of tumors of the pericardium and in cases of acute or chronic mediastinitis in which the pericardium has become inflamed, thickened and necrotic or has become involved in adhesions between the heart and the chest wall.

The views on the subject are divergent. Barnard [47] found in experiments on preparations of the heart and pericardium removed from cats that the heart without its pericardium ruptured under a pressure of one atmosphere, whereas the pressure required to rupture the heart with the pericardium intact was one and three fourths atmospheres. From that, he concluded that the pericardium was necessary in life to prevent dilatation of the heart. Kuno,[48] experimenting with heart-lung preparations, found that an increased venous pressure caused hemorrhage into the walls of the heart, and concluded that the existence of the pericardium was necessary for the unimpaired function of the heart in normal life. Amerio,[49] in experiments on rabbits, found that the margin of the pericardium remaining after partial resection became adherent in places to the chest wall, but that, after total resection of the pericardium, no adhesions were found between the heart and the surrounding organs. These procedures, he found, did not affect the life of the animal, and he concluded that, in human cases, the pericardium, when involved by tumors of the chest wall, could be resected without fear of endangering life. Parlavecchio [50] performed similar

47. Barnard, H. L.: The Functions of the Pericardium, J. Physiol. **22**:43, 1898.

48. Kuno, Yas: The Significance of the Pericardium, J. Physiol. **50**:1, 1915-1916.

49. Amerio, V.: Contributo Clinico-Sperimentale allo Studio delle Ferite del Pericardio. Atti d. XI. Cong. med. Internaz., Roma, **4**:301, 1894.

50. Parlavecchio: Experimentelle Perikardiektomie und ihre Möglichen Therapeutischen Anwendungen, Deutsch. Ztschr. f. Chir. **98**:126, 1909.

operations on ten dogs, and noted, in each case, a pronounced loss of weight and, at necropsy, observed an hypertrophy of the left ventricle. The size of the heart, however, was not followed by roentgen-ray studies. Rehn [42] performed total or partial pericardiectomy on five dogs, and in no case did he observe any effect on the health of the dog. No adhesions were found at necropsy, and no histologic changes were found in the heart muscle. Mazzone [51] removed the pericardium from seven dogs, and found that the operation had no effect on the animals. Yamada,[52] by making a long incision in the pericardium so as to nullify the effect of the pericardium on the heart, was unable in a series of fourteen dogs to obtain the findings observed by Kuno in heart-lung preparations. During the postoperative period, the dogs were exercised by running. Dilatation of the heart did not occur, and in no case was intramural hemorrhage found. From these experiments, Yamada concluded that the protective influence of the pericardium was not of great significance.

In none of the work mentioned above were the animals subjected to strenuous exercise, and the desirability of studying the capacity of the heart to perform a greatly increased amount of work suggested that the animals be exercised to the point of fatigue. To produce fatigue in dogs is not without difficulty. On treadmills, normal dogs can run 30 miles without showing signs of marked fatigue, and, likewise, normal dogs can swim for several hours without exhaustion. The latter method [53] was adopted, but in no instance were the dogs visibly exhausted.

Pericardiectomy was performed in the following five experiments:

EXPERIMENT 20.—A male mongrel, weighing 8.1 kg., was operated on, April 9, 1924; the anterior part of the pericardium, about 50 sq. cm. in area, was resected. In the roentgenograms, the cardiac shadow before operation was 5.8 cm.; six days postoperative, 6 cm.; fifteen days, 6 cm.; thirty days, 6 cm.; fifty-seven days, before swimming, 6.1 cm., and immediately after swimming, 5.8 cm. The dog, throughout this period, was in good condition, did not lose weight, and had no cardiac murmur. On the fifty-seventh day, the dog swam vigorously for thirty minutes without showing any marked signs of fatigue. The pulse rate before swimming was 98; after swimming, 172, and in the course of forty-five minutes returned to normal. At necropsy, the lungs were negative. The heart lay in the left pleural cavity, the mediastinum on the right being in contact with the heart but not adherent to it. The remaining portion of the

51. Mazzone, F.: Contributo Sperimentale alla Pericardiectomia, Centralbl. f. Chir. **39**:1046, 1912.

52. Yamada, M.: Ueber die Bedeutung des Perikardiums, Mitt. a. d. med. Fakult. d. k. Univ. zu Tokyo **16**:527 (Feb.) 1917.

53. A tank 5 feet square and 4 feet deep was constructed. By horizontal traction on the tail, the dog could be made to swim continuosly in the center of the tank.

pericardium lay posteriorly. Over the entire surface of the heart was a thin, fibrinous structure. Between the healed edge of the pericardium and the heart were a few small adhesions.

EXPERIMENT 21.—A male collie, weighing 18.6 kg., was operated on, April 12, 1924, the anterior portion of the pericardium, about 50 sq. cm., being excised. In the roentgenograms, the cardiac shadow before operation was 8 cm.; after operation, 7.8 cm.; three days after, 7.3 cm.; twelve days, 7.1 cm.; twenty-seven days, 7.6 cm.; fifty-four days, before swimming, 6.5 cm., and immediately after swimming, 6.8 cm. The dog was exercised for one hour by vigorous swimming, at the end of which time no striking signs of fatigue were shown. The pulse rate at the end of swimming was 172, and it returned to normal in twenty-five minutes. Throughout the postoperative course, the dog was in good condition. The lungs were negative. There were no adhesions to the operative scar in the chest, nor to the heart. The pericardium was nowhere adherent to the heart. The surface of the heart was covered by a thin layer of fibrous tissue.

EXPERIMENT 22.—A shepherd, weighing 25.6 kg., was operated on, April 14, 1924, about 40 sq. cm. of pericardium being removed. In the roentgenograms, the cardiac shadow before operation was 7.8 cm.; three days after operation, 8 cm.; seven days after, 7.7 cm.; ten days, 8 cm.; twenty-seven days, 8 cm.; fifty-two days, before swimming, 7.4 cm., and immediately after swimming, 7.8 cm. Throughout the postoperative period, the dog was in good condition. The dog was exercised by vigorous swimming for forty-five minutes, and at the end of this time showed no signs of fatigue. The heart rate had increased to 168, and in the course of one hour returned to normal. The lung was adherent to the scar in the chest but not adherent to the heart. There were no adhesions to the heart anteriorly. The posterior portion of the pericardium was present, and about one fifth of its margin was adherent to the heart. A fibrous film attached to the epicardium covered the heart anteriorly (Fig. 9).

EXPERIMENT 23.—A mongrel female, weighing 10.6 kg., was operated on, April 26, 1924, a total pericardiectomy being performed. In the roentgenograms, the cardiac shadow before operation was 5.7 cm.; three days after operation, 6.4 cm.; six days after, 5.7 cm.; thirteen days, 6.3 cm.; forty days, before swimming, 6.8 cm., and immediately after swimming, 6.4 cm. The dog was exercised vigorously by swimming for thirty minutes without showing fatigue. The pulse rate immediately after swimming was 132, and returned to normal in thirty-three minutes. The lungs were negative and not adherent to the chest wall. A small adhesion was present between the lung and the ear of the left auricle. Mediastinal fat was adherent to the base of the heart on the right. There were no other adhesions. The denuded surface of the heart was covered with fibrous film.

EXPERIMENT 24.—A female collie, weighing 11 kg., was operated on, March 29, 1924, an incision being made in the left ventricle. Two Lembert sutures of silk closed the wound. The anterior portion of the pericardium was removed. In the roentgenograms, the cardiac shadow before operation was 6 cm.; eleven days postoperative, 6.6 cm.; seventeen days, 6.6 cm.; twenty-three days, 7 cm.; twenty-seven days, 7.1 cm.; forty-one days, 7.2 cm.; sixty-eight days, before swimming, 7.1 cm., and immediately after swimming, 6.9 cm. The dog was in good health following the operation. The dog swam vigorously for thirty minutes without fatigue. The pulse rate after swimming was 140, and in ten minutes fell to 110. The lung was adherent to the scar in the chest, but not adherent

to the heart. The heart lay in the left pleural cavity. The right mediastinal membrane was in contact with the right half of the heart, but not adherent to it. The posterior part of the pericardium showed numerous adhesions to the heart. The heart was covered with a newly formed layer of connective tissue.

Fig. 9.—Margin of the pericardium after partial pericardiectomy on right, not sealed to the heart; newly formed layer of connective tissue over anterior surface of heart.

Following pericardiectomy, the general health of the dog did not seem to be impaired. The response to exercise did not vary appreciably from the normal. Vigorous swimming for from thirty to sixty minutes was tolerated without the dog's showing signs of fatigue, and the pulse showed no variation from that of normal dogs subjected to the same

exercise. The roentgen-ray studies of the heart following pericardiectomy are not conclusive. In two (Cases 20 and 22), there was no significant change in the size of the heart; in one (Case 21), there was a decrease in size, and in two (Cases 23 and 24), one of which had the added factor of an operative scar in the left ventricle, there was an increase in size. In one case, following pericardiectomy, no adhesions to the heart were found. The incised margin of the pericardium became adherent in places to the heart, but in no case did it everywhere become sealed to the heart. In one case, the lung became adherent to the left auricle.

That the pericardium is not essential to life is shown by cases of congenital defects of the pericardium without impairment to health. Sixty-four cases are recorded in the literature, none of which produced clinical symptoms, and in no instance was the defect regarded as responsible for death. Descriptions of forty-two of these cases were obtainable, in twelve of which adhesions between the heart and its adjacent structures were present, and, in four, an enlargement of the heart was found.

IV. SUMMARY

The pericardium is very sensitive to mechanical trauma, hot salt solution, chemical irritants and infection. Any of these may be followed by the formation of cardiopericardial adhesions. The presence of blood in the pericardium per se is of no consequence in the formation of adhesions. The adhesion that usually forms between the pericardium and the incision made in the left ventricle for the introduction of the cardiovalvulotome is not avoided by the transplantation of fat into the pericardium.

Pericardial effusions may follow operations on the heart. In those cases [1] in which cardiopericardial adhesions are divided at operation, effusion into the pericardium may assume a serious aspect. Pericardiectomy is tolerated well by animals. It is probable that the tamponade produced by a rapidly forming effusion into the pericardial cavity can be avoided by incomplete closure of the pericardium without appreciable impairment to the functional capacity of the heart. In human cases in which the Duval Barasty [54] median thorocotomy exposure is used and in which the pleural cavities are not opened, compression of the heart by the formation of fluid in the pericardial cavity can probably be avoided by incomplete closure of the pericardium so that the fluid can escape into the mediastinum. Because of the sensitivity of the visceral and parietal pericardium to trauma, the

54. Duval, P., and Barasty, P.: De la Péricardotomie Thoraco-abdominale Mediane (Chirurgie du Cœur et des Grands Vasseaux de la Base), Presse méd. 26:437 (Aug. 29) 1918.

insertion of a drain into the pericardial cavity in noninfected cases is not advisable. The incised margin of the pericardium does not become intimately adherent to the heart, and the presence of a drain is unnecessary to insure the free escape of fluid.

The observance of certain technical points is of great importance in cardiac surgery. The heart should be handled delicately. Injury to the pericardium as produced by sponging should be avoided. Hot salt solution at a temperature above 105 F. should not be used to stimulate the heart action. A rigid aseptic technic should be observed. These points of technic are of great importance in cardiac surgery if intrapericardial adhesions and a rapidly forming pericardial effusion producing heart tamponade are to be avoided.

EXPERIMENTAL HYDRONEPHROSIS

THE EFFECT OF CHANGES IN BLOOD PRESSURE AND BLOOD FLOW ON ITS RATE OF DEVELOPMENT

I. Splanchnotomy: Increased Intrarenal Blood Pressure and Flow; Diuresis *

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INTRODUCTION

The relative importance of filtration, diffusion, absorption, reabsorption, and secretion to the formation of the urine is still an unknown and disputed problem. None of the theories of renal secretion, nor any of their many modifications, satisfactorily meet the requirements in respect to many details of a fair minded majority. An old well-known obstacle is hydronephrosis. This unique condition, particularly with complete ureteral obstruction, raises some doubt of its true relation to the foregoing factors of renal function. So far, no adequate explanation of hydronephrosis has been presented, and this failure might at first be looked on as the very natural result of our ignorance of the factors that control renal secretion itself. But, on the other hand, it is also possible that this most interesting pathologic condition depends on other factors than those concerned simply with the formation of the urine. That the continued formation of urine after ureteral obstruction, even when complete, is essential to the production of hydronephritic atrophy is self evident. An anuria following ureteral block leads to primary renal atrophy, a quite different thing in pathology. But the relative influence of blood pressure and flow and concentration or of filtration, absorption and secretion in hydronephrosis is problematic. The uniform constant progression of hydronephrotic atrophy, as experimentally seen (in the rat and rabbit), rather minimizes the significance of these several secretory factors. Continued activity of renal tubules, if only a few, presupposes an outlet, and, when a ureter is completely blocked, the only outlet heretofore conceived has been tubular reabsorption, but,

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among other difficulties, the low concentration of all constituents of the sac contents of late hydronephrosis is difficult of explanation by tubular absorption as threshold and nonthreshold substances have all been equally absorbed. Substances that normally are not supposed to be absorbed (urea), under conditions of pelvic obstruction, apparently are absorbed with ease.

In spite of these more or less theoretic objections of the application of theories of renal secretion to the pathogenesis of hydronephrosis, it was thought worth while to test the value of some recognized factors in the formation of the urine to hydronephrosis by experimentally modifying some of these factors over long periods, thus increasing (diuresis) or diminishing (oliguria) urine formation, and studying the effect of such changes on the rate of development of hydronephrosis. The alteration of any particular active factor in hydronephrosis would be at once recognized in the more or less respective rapid production of hydronephrosis than in an undisturbed control series.

It is possible by a number of experimental procedures to effect changes in intrarenal blood pressure and blood flow, but obviously only those which will give alterations for prolonged periods will meet the requirements of this particular problem. Increased or diminished intrarenal blood pressure for a period of several weeks or months, other factors being constant, would be expected to hasten or delay respectively hydronephrotic atrophy, provided intrarenal pressure is a factor of moment in its development. Partial obstruction of the renal vein raises intrarenal pressure; of the renal artery, lowers it; and of either slows the blood stream and produces an oliguria. Prolonged diuresis *a priori* might be regarded as of importance, but there are so many kinds of diuresis that analysis and interpretation of results is difficult. Splanchnotomy, by vasodilatation and increased blood flow, produces a prolonged diuresis quite different in cause from that produced by forced fluids with salt and urea. The ineffectiveness on hydronephrosis of salt, urea, diuretin, digitalis and water diuresis and of oliguria produced by ingestion methods has already been determined.[1] A study of the effect of more direct alteration of intrarenal pressure and blood flow has since been completed, and the experimental results of the effect of changes in blood pressure and blood flow on the rate of development of hydronephrotic atrophy for convenience of brevity and emphasis will be presented in a series of three papers: I, Splanchnotomy; II, Partial Constriction of the Renal Artery, and III, Partial Constriction of the Renal Vein.

1. Hinman, Frank; and Belt, A. E.: J. Urol. 9:397-417 (May) 1923.

SPLANCHNOTOMY AND ITS EFFECT ON RENAL SECRETION

It has been firmly established that unilateral splanchnotomy produces a diuresis from the kidney of the side operated on. Bernard [2] first demonstrated this in 1859, and since that time his findings have been controverted by but two investigators, Schwarz [3] and Peyrani,[4] both of whom report a diminished volume of urine under the same conditions. But to offset this are the confirmations of Vogt,[5] Klecki,[6] Eckhard,[7] Greck,[8] Knoll,[9] Jungmann and Meyer,[10] Rhode and Ellinger,[11] Quimby,[12] Marshall and Kolls,[13] Marshall and Crane,[14] Ellinger [15] and Yoshimura,[16] all of whom have demonstrated a diuresis on the side operated on.

The opinion is not so unanimous as to the cause of this diuresis. It is usually attributed entirely to vasomotor influences.[13] Some investigators, however, insist on the presence, in the splanchnics, of secretory or inhibitosecretory fibers which have a specific action on the renal cells. Among these are Jost,[17] who claims the existence of inhibitosecretory fibers. Rhode and Ellinger [18] also conclude that the splanchnics have a specific inhibitosecretory action on the renal secretion which cannot be explained by vasomotor influences. Others who infer that a specific nerve regulation of renal activity may exist are Jungmann and Meyer,[10] Asher and Pearce [19] and, recently, Addis, Shevky and Bevier.[20] The work of Jost, Rhode and Ellinger and Asher and Pearce has been justly criticized by Cushny,[21] who believes that their results are inconclusive. There seems to be a preponderance of evidence to indicate

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2. Bernard, Claude: Lecons sur les proprietes physiologiques des legendes de l'organisme, 1859.
3. Schwarz: Arch. f. exper. Path. u. Pharmakol. **43**:1, 1900.
4. Peyrani: Biol. Centralbl. **1**:599, 1881-1882.
5. Vogt: Arch. f. Anat. u. Physiol. (Physiol. Sections), 1898, p. 399.
6. Klecki: Arch. f. exper. Path. u. Pharmakol. **39**:173, 1897.
7. Eckhard: Beitr. z. Anat. u. Physiol. **4**:153, 1869.
8. Greek: Arch. f. exper. Path. u. Pharmakol. **68**:305, 1912.
9. Knoll: Beitr. z. Anat. u. Physiol. **6**:41, 1872.
10. Jungmann and Meyer: Arch. f. exper. Path. u. Pharmakol. **63**:49, 1913.
11. Rhode and Ellinger: Zentralbl. f. Physiol. **27**:12, 1913.
12. Quimby, W. C.: J. Exper. Med. **23**:535 (April) 1916.
13. Marshall, E. K., Jr., and Kolls, A. C.: Am. J. Physiol. **49**:302 (July) 1919.
14. Marshall, E. K., Jr., and Crane, M. M.: J. Physiol. **62**:330 (Oct.) 1922.
15. Ellinger: Arch. f. exper. Path. u. Pharmakol. **90**:77, 1921.
16. Yoshimura: Tohoku J. Exper. Med. **1**:113, 1920.
17. Jost: Ztschr. f. Biol. **64**:441, 1914.
18. Rhode and Ellinger (Footnotes 11 and 15).
19. Asher and Pearce: Ztschr. f. Biol. **63**:83, 1914.
20. Addis, T.; Shevky, A. E., and Bevier, G.: Am. J. Physiol. **46**:129 (June) 1918.
21. Cushny, A. R.: The Secretion of the Urine, London, 1917.

that the renal nerves do not contain secretory fibers. Carrel and Guthrie,[22] Lobenhoffer [23] and Quimby [12] have studied the secretions of the denervated transplanted kidney, and found an apparently normal function, and, furthermore, that such a kidney could maintain life after the removal of its fellow. Quimby concluded that the evidence does not support the supposition of secretory nerves, but that vasomotor conditions can account for all the changes present.

The splanchnics are the vasomotor nerves of the kidney.[21] Jost [17] has claimed to have demonstrated other paths, and Cohnheim and Roy [24] and Richards and Plant [25] have noticed vasomotor phenomena when both splanchnics were sectioned. Nevertheless, it has been firmly established that the splanchnics contain the bulk of the vasoconstrictor fibers, and that their section results in vasodilatation with increased blood flow through the kidneys.[26] That this is sufficient to account for the resulting diuresis has been demonstrated in the comprehensive study by Marshall and Kolls [13] of the relation of the renal nerves to renal secretion. They conclude that the marked diuresis of the kidney on the side operated on, after unilateral splanchnotomy, is due to vasodilatation and increased blood flow, and that it persists for months. Their work has been confirmed by Yoshimura [16] and since repeated and extended by Marshall and Crane.[14] The importance to our study of the duration of these changes is evident. Quimby [12] noted, in the denervated kidney, that the diuresis lasted for from ten to fourteen days, at which time the balance between the two kidneys was regained so that each organ divided the work equally. On the other hand, Rhode and Ellinger [11] state that the diuresis lasts for months. We may conclude, therefore, that in unilateral splanchnotomy we have a procedure that will produce a unilateral diuresis, due to vasodilatation and increased blood flow through the one kidney, which will persist for several weeks.

EXPERIMENTAL FINDINGS AND TECHNIC

The left kidney of rabbits was exposed, under surgical asepsis and ether narcosis, through a vertical lumbar incision, and the ureter divided between ligatures about 4 cm. from the pelvis. In one series, the peritoneum was then pushed forward and inward, exposing the pillar of the diaphragm extraperitoneally. Between this and the psoas, the splanchnics run downward into the perirenal fat behind the suprarenal gland

22. Carrel and Guthrie: Compt. rend. Soc. de biol. **2**:669, 1905.
23. Lobenhoffer: Mitt. a. d. Grenzgeb. d. Med. u. Chir. **26**:198, 1913.
24. Cohnheim and Roy: Virchows Arch. f. path. Anat. **92**:424, 1883.
25. Richards, A. N., and Plant, O. H.: Am. J. Physiol. **59**:144-183 (Feb.) 1922.
26. Cushny (Foonote 21). Burton-Opitz and Lucas: Arch. f. d. ges. Physiol. **127**:143, 1909.

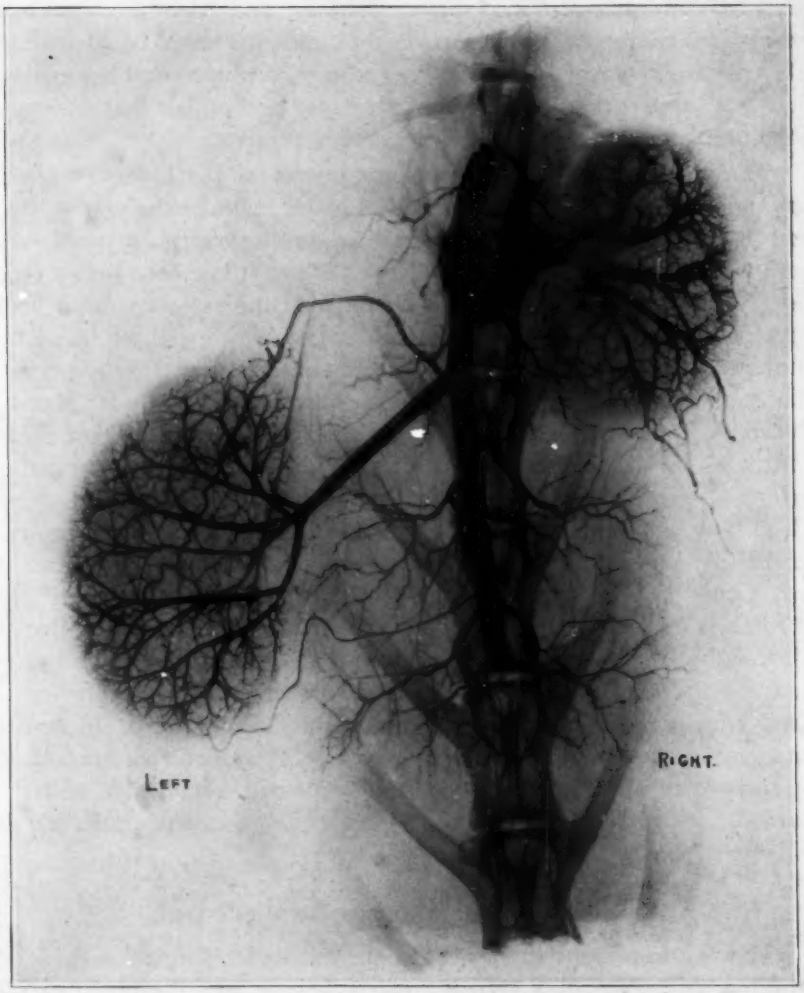

Fig. 1.—Roentgenographic appearance of arterial barium sulphate injection of a twenty-one day hydronephrosis; elongation and narrowing of the interlobar vessels in the hydronephrotic left kidney. Of special interest are the changes in the primary divisions of the renal artery at the hilum and in the sinus renalis. On the right side (normal kidney) after the division, the primary branches enter the sinus in an arched manner with the concavity facing the aorta. This change of contour is brought about by the distention of the renal pelvis, and attests to the pressure that must be exerted on the primary arterial divisions in hydronephrosis.

which appears as a buff-colored body about the size of a small pea. The nerves were radically divided at this point and the ureter tied and divided, and the wound was closed. In a control series, the ureter only was similarly tied and divided.

The animals were put on a regular food and water allowance, and both control and splanchnotomized animals were killed seven, fourteen, twenty-one, twenty-eight, fifty-six and ninety days following operation. At necropsy, the kidneys were examined for gross changes, and division of the nerves of the one series was confirmed. Arterial barium sulphate injections were made in situ, and stereoscopic roentgenograms were taken (Fig. 1). This method demonstrates the grosser circulatory

TABLE 1.—*Measurements of Hydronephrotic Kidney in Rabbits After Total Ligation of Left Ureter (Control Series)*

Duration, Days	Weight of Rabbits, Kg.	Measurements of Kidney			Pelvic Capacity, C.c.
		Length, Cm.	Depth, Cm.	Width, Cm.	
7	4	5.2 (1)*	3.5 (0)	3.3 (3)	4
14	2.72	4.3 (0.55)	3 (0.48)	2.8 (0.74)	6
21	4	6 (0.9)	4.4 (0.4)	3.8 (0.76)	14
28	3.02	5 (1.13)	3.4 (0.38)	3.5 (1.21)	13
56	3	5.2 (1.36)	3.7 (0.7)	3.5 (1.22)	25
90	2.80	5.5 (1.8)	3.8 (0.91)	3.6 (1.41)	33

* The figures in parenthesis indicate the actual increase in size of the kidney. They are obtained by proportioning the weight of the animal and the measurements to those of a normal rabbit weighing 2.5 kg., whose left kidney is 3.2 cm. long, 2.5 cm. deep and 1.9 cm. wide.

TABLE 2.—*Measurements of Hydronephrotic Kidney After Total Ligation of Left Ureter and Splanchnotomy on the Same Side*

Duration, Days	Weight of Rabbits, Kg.	Measurements of the Kidney			Pelvic Capacity, C.c.
		Length, Cm.	Depth, Cm.	Width, Cm.	
7	3.07	4.2 (0.27)*	3 (0)	2.7 (0.37)	3
14	4.09	5.6 (0.37)	4.6 (0.51)	3.7 (0.6)	10
21	2.89	4.8 (1.11)	3.2 (0.31)	3.3 (1.1)	14
28	3.44	5.5 (1.10)	4 (0.56)	3.9 (1.29)	16
56	3.25	5.5 (1.34)	4.1 (0.85)	3.7 (1.23)	20

* The figures in parenthesis indicate the actual increase in size when the measurements are proportioned to the animal's weight, using as a normal standard a rabbit weighing 2.5 kg., whose left kidney is 3.2 cm. long, 2.5 cm. deep and 1.9 cm. wide.

changes occurring in hydronephrosis, and is especially valuable in our study as an index of any slight difference in rate of development. The pelvic capacity was also measured, and, in some instances, pyelograms were taken. The kidneys were then sectioned sagittally and accurately measured as to length, depth and width. Microscopic sections of specimens of the same period of obstruction of the two series were then subjected to comparative studies.

A comparison of these measurements with those shown in Table 2 indicates that splanchnotomy influences very little, if at all, the ordinary rate of development of hydronephrosis with complete ureteral obstruction.

FINDINGS

In the control series, a very uniform progressive development of hydronephrosis after complete unilateral ureteral obstruction is found. Rarely, slight variations occur, but the degree of hydronephrosis is

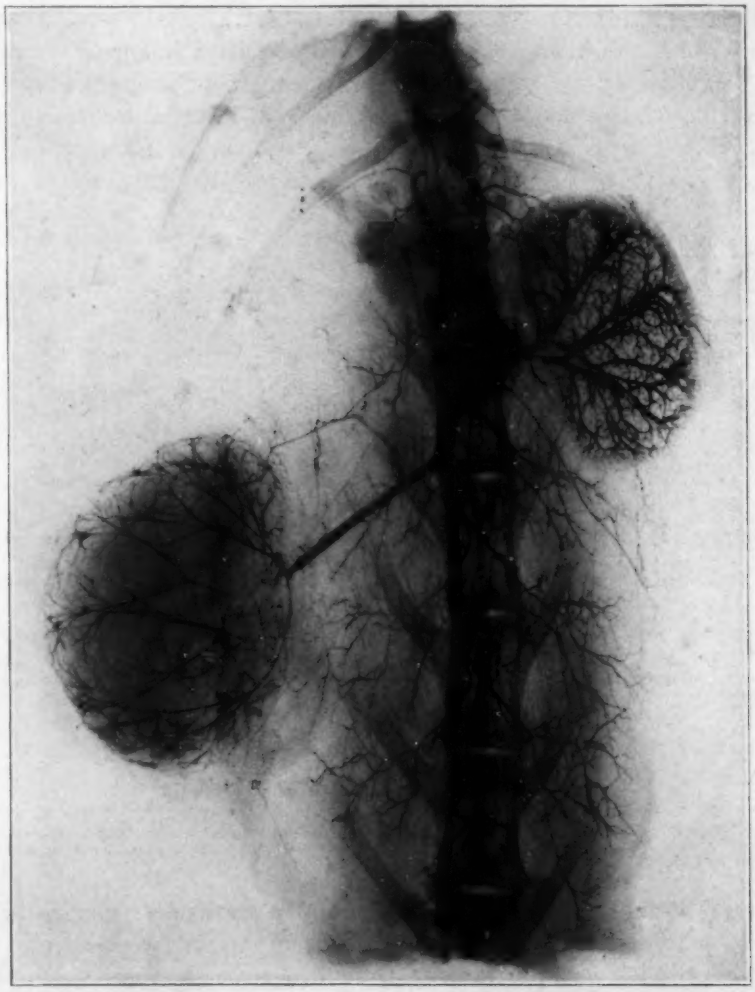

Fig. 2.—Roentgenographic appearance of an arterial barium sulphate injection of a fifty-six day hydronephrosis; thinning out and evident compression of the arterial tree.

surprisingly proportional to the duration of the obstruction [27] (Table 1). At first glance, the measurements do not seem to indicate uniformity,

27. Ponfick: Beitr. z. path. Anat. u. z. allg. Path. 49:127-212, 1910. The author has noted this progressive development of hydronephrosis in rabbits, and his published measurements correspond approximately to ours.

but the apparent discrepancy disappears on correcting the figures in proportion to the weight of the different animals.

The grosser circulatory changes occurring in hydronephrosis, as demonstrated by roentgenograms after arterial barium sulphate injections, is well illustrated by comparison of Figures 1 and 2, a twenty-one and fifty-six day specimen of the control series. The lower kidney (left) is the hydronephrotic one, and the difference of its gross arterial architecture from that of the normal right kidney and the fifty-six day hydronephrosis is interesting. The elongation and narrowing of the interlobar vessels is marked, but of especial interest are the changes in the primary divisions of the renal artery at the hilum and in the sinus renalis. In the normal right kidney (upper), after division at the hilum, the primary branches enter the sinus in an arching manner with the concavity facing the aorta. In the hydronephrotic kidneys, this arch is reversed, and the convexity faces the aorta. This change of contour is brought about by the distending renal pelvis, and attests to the pressure that must be exerted on these primary arterial divisions in hydronephrosis.

Microscopically, the changes are those that have been repeatedly observed in hydronephrosis, and no difference between the two series could be noted. The early tubular dilatation with a certain amount of round cell infiltration and hyaline change and the later tubular dilatation and atrophy is equally marked in both. The same general atrophy with connective tissue substitution and sclerosis occurs, with areas or nodules of remarkable glomerular preservation.

CONCLUSIONS

1. After complete unilateral ureteral obstruction in rabbits, there is a uniform progressive development of hydronephrosis and the degree of hydronephrotic atrophy is uniformally proportional to the duration of the obstruction.

2. Unilateral splanchnotomy causes a diuresis on the side operated on by reason of intrarenal vasodilatation and increased blood flow through the kidney, and this diuresis persists for long periods.

3. Unilateral splanchnotomy combined with complete ligation of the ureter does not influence in any way the ordinary rate of development of hydronephrosis following simple complete ligature.

PRIMARY BILATERAL CARCINOMA OF THE FALLOPIAN TUBES*

RECOGNITION OF EARLY METASTASIS ESSENTIAL TO SUCCESSFUL TREATMENT: REPORT OF A CASE

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The similarity in symptomatology between primary carcinoma of the fallopian tubes and salpingitis, the rarity of the disease, the paucity of correct preoperative diagnoses and the fact that the condition is often recognized only histologically make it imperative to report all cases. In addition, the youth of our patient and the early involvement of the uterus, as shown by microscopic examination, are interesting items worthy of note. Like most of the cases in the literature, the one we are reporting was diagnosed as salpingitis and a double salpingectomy was performed, the true nature of the disease not being suspected until after the operation.

REPORT OF CASE

History.—M. A. D., a woman, aged 25, with a negative family history, except that her mother died of pulmonary tuberculosis at the age of 40, stated that she had had sleeping sickness, in 1916, and was confined to bed for three weeks. There were no complications, and recovery was complete.

The patient first menstruated when 13; the periods were regular, of four days' duration and painless. She was married at 16 and gave birth to two children, the first when she was 18. Labor was difficult; instruments were used, and she was badly torn externally. The perineum was repaired one year later. The second child was born when the patient was 21. At this time, she had a slight external laceration requiring two stitches. Periods returned one year after delivery. Following this, she usually mentsruated every two weeks, menstruation being scant and painless. This continued until June, 1921, when the periods appeared at irregular intervals, varying between two and eight weeks. The duration was from two to five days, and they were scant in amount.

The present illness began, July 13, 1922, when she developed lower abdominal pain, fever, dysuria and constipation, accompanied by slight nausea but no vomiting. She stated that she had leukorrhea, which had been more profuse the last few days.

Physical Examination.—The temperature was 102.4; respirations, 22; pulse, 100. The heart and lungs were negative. The abdomen was moderately distended, with marked tenderness in the lower portion but no marked rigidity. Vaginal examination revealed a foul, yellowish discharge; the cervix was edematous; there was slight rectocele. The uterus was not enlarged. Both fallopian tubes were enlarged and tender. The ovaries were moderately enlarged and tender. The diagnosis was acute salpingitis.

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The patient was sent to the Samaritan Hospital. A cervical smear revealed many gram-negative bacilli, occasional gram-positive cocci and occasional gram-negative diplococci, not morphologically resembling gonococci. Blood examination showed a leukocytosis of 32,800; polymorphonuclears totaled 77 per cent. Modified Oschner treatment was instituted, and she was discharged from the hospital ten days later. Following this, the leukorrhea gradually diminished under local treatment, but she complained of lower abdominal discomfort due to the enlarged, supposedly infected tubes.

Operation and Result.—August 24, both fallopian tubes and appendix were removed under spinal anesthesia. When the abdomen was opened a slight quantity of blood-stained fluid was noticed. The uterus was of normal size; the ovaries were slightly atrophic and nonadherent. Both tubes, however, were enlarged to three times their normal size, the enlargement being about 1 cm. at the uterine ostium, increasing to about 5 cm. in the midportion of the tube, and gradually diminishing to the fimbriated end, where it reached a diameter of about 3 cm. The two tubes were of about the same size, and both fimbriae were completely closed; there was no evidence of any adhesions to the ovaries or other organs. The tubes were not opened until after the operation was completed. Before section, it was noticed for the first time that they were rather firmer than the usual pyosalpinx; when both tubes were incised, the yellowish villous contents projected markedly, everting the cut edges so that the interior of the tube presented a convex surface. A slight amount of blood-stained fluid escaped.

Following the operation, the patient complained of slight dysuria and a moderate amount of purulent leukorrhea. A hysterectomy was advised. This was refused, but consent was obtained for a radium treatment. This was given, November 4, at the American Stomach Hospital. The capsule was placed high in the fundus for a total of 600 mg. hours. She was again seen, December 22. At this time, she was complaining of sharp pain in the right side of the lower part of the abdomen, cramplike in character, usually relieved by sitting. There were three or four small watery evacuations daily. She also complained of dysuria and leukorrhea, the latter yellowish. Feb. 8, 1923, she was readmitted to the American Stomach Hospital, and consent was obtained to remove the uterus. This was done, February 10, under spinal anesthesia. The uterus was small, measuring 6 by 4 by 3 cm. It was removed close to the internal os; the ovaries were small and appeared normal; there were no adhesions present and no evidence of disease elsewhere. (As six months had elapsed since the previous operation, it was felt that the ovaries would show some gross change in the interval if they had been involved.) She was discharged from the hospital, seventeen days after the operation, returned to the clinic on one or two occasions, and then ceased coming. It was our intention to insert large amounts of radium into the cervix. This, of course, we were unable to do. In July, 1924, we received a letter stating that she was in good health and was applying for admission to a training school for nurses.

Pathologic Report.—Sections from the infundibulum, ampulla and isthmus of both tubes gave essentially corresponding histologic pictures. Sections from the ampulla showed delicate branching processes of loose and vascular connective tissue, covered for the most part by quite regular columnar epithelium, the whole springing from the wall of the tube. In a few areas, the regularity of the individual cells and their relationship to each other and to the underlying tissues was lost, and reduplication of the covering epithelial layer resulted.

There was noticeable irregularity in size of the individual epithelial cells with vacuolization, in many instances. In places on the inner wall of the tube, the epithelium dipped below the surface, producing somewhat imperfectly formed glands. In scattered areas, deep below the inner surface of the tube were low columnar epithelial cells in the form of glandular acini, some quite perfectly formed, others irregular. The muscular coat of the tube showed a small amount of loose, fibrous connective tissue, with slightly thickened and

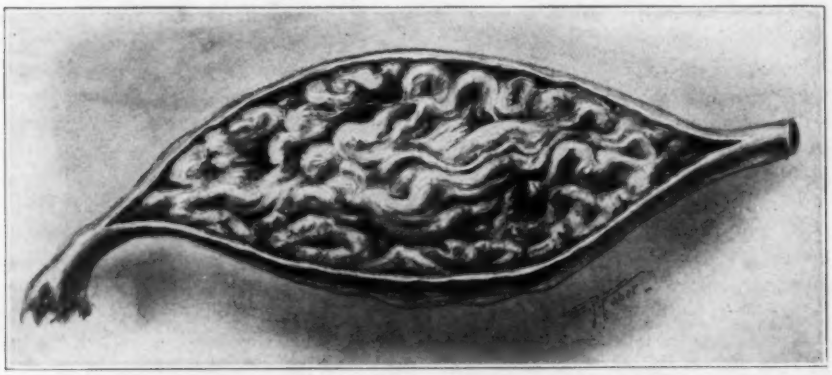

Fig. 1.—Appearance of tube on section: thin wall, papillomatous contents and closed fimbriated end.

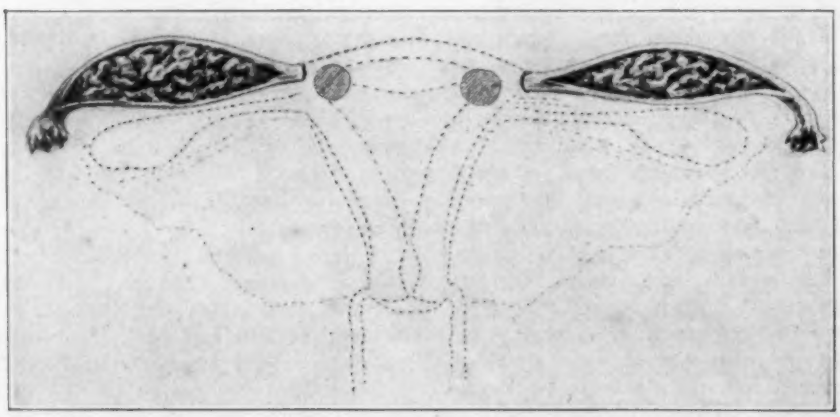

Fig. 2.—Circular shaded areas indicate portion of cornua involved (Fig. 7); actual area is not quite so large as represented.

congested blood vessels, and areas of round cell infiltration. These, for the most part, consisted of lymphocytes, and while they were scattered generally throughout the muscular coat, they tended to accumulate just beneath the mucosa and, to a lesser extent, around the blood vessels.

As the isthmus of the tube was approached, the papillomatous projections from the wall of the tube became shorter and the branching diminished. The epithelial cells covering these projections appeared to increase in size and

"vigor," for they stained more deeply. There also was a greater tendency for a reduplication of the hypertrophic and hyperchromatic epithelial layer. Vacuolization increased as well. The general characteristics of the wall, as described above, still held, with here and there isolated groups of epithelial cells in gland formation.

Sections through both cornua of the uterus, with the contained tubal canal, still showed a hyperchromatism and slight hypertrophy of the individual epithelial cells, with the beginning development of a cellular mucosa more characteristic of the uterine endometrium; on both sides of the canal of the tube were again a few glandular acini of irregular size lined by vacuolated low columnar epithelial cells. These, for the most part, were fairly regular in their relation to the surrounding tissue, but here and there showed a distinct break through the basement membrane, at points where the individual cells had lost their normal relationship to each other. Sections through the body of the uterus and endometrium, in several places, did not show any evidence of malignancy.

The pathologic diagnosis was bilateral malignant papilloma of the fallopian tubes, with involvement of the uterine cornua.

Close analysis of this case and those in the literature shows several points of interest and importance. So far as we have been able to find, our patient is the youngest on record (25 years old). Most cases fall between the fourth and fifth decade with extremes of 27 (Norris [1]) and 70 (Novy [2]). In the majority of cases, there has been a previous history of pelvic inflammatory disease, often with attacks of cramplike pain accompanied by a watery, blood stained leukorrhea and metrorrhagia or menorrhagia. In the case reported there is a history of irregular menstruation for over a year, followed by an attack diagnosed as acute salpingitis, but at no time could a history be elicited of the characteristic watery, blood stained leukorrhea.

Another unusual feature was the presence of blood stained fluid in the peritoneal cavity. Note of this was made at the time of operation, but probably insufficient importance was attached to it, in view of the attack of acute salpingitis six weeks before, although it is a most uncommon finding in this condition. No thought of a malignant process occurred, since the uterus, ovaries, intestines and peritoneum were visibly clear.

In the vast majority of cases, the condition at operation simulates a hydrosalpinx or a pyosalpinx. The fimbriated end of the tube is closed and frequently adherent to the ovary, quite commonly being associated with a cyst, while the infundibulum and the ampulla are concerned in a dilatation, which, with the uninvolved isthmus, produces an organ of club or retort shape. Primary carcinoma of the fallopian tube is most commonly unilateral, although we have found forty-three bilateral as against ninety-three unilateral. Vest [3] explains bilateral involvement as a metas-

1. Norris, C. C.: Surg., Gynec. & Obst. **8**:272-278, 1909.
2. Novy: Monatschr. f. Geburtsh. u. Gynäk. **11**:6, 1900.
3. Vest, C. W.: Bull. Johns Hopkins Hosp. **26**:305, 1914.

tasis of malignant cells traversing the path followed in transmigration of the ovum, a mode of transmission difficult to understand, if its abdominal end closes early, as Doran states, which point has also been used as an argument in favor of a primary bilateral carcinoma by Kalmann [4] and Schäfer.[5] The carcinoma generally springs from the ampulla or middle third of the tube and is of two types, according to Sänger and Barth,[6] the papillary or the alveolar form, the former being the most frequent, and usually primarily malignant, although degeneration of a benign papilloma

Fig. 3.—Infundibular portion of tube, showing papilloma; reduplication and irregularity of epithelial layer, also penetration into tube wall at lower margin.

may occur. Kehrer [7] believes the papillary to be an earlier form from which the alveolar develops, and is supported in this view by Küstner [8] and Stübler.[9]

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4. Kalmann, W.: Wien. med. Wchnschr. **72**, 1922-1923.
5. Schäfer, P.: Zentralbl. f. Gynäk. **47**:1, 1922; ibid. **47**:357 (March 3) 1923.
6. Sänger-Martins: Krankheiten der Eileiter, p. 253, 1895.
7. Kehrer: Monatschr. f. Geburtsh. u. Gynäk. **27**:327, 1908.
8. Küstner, H.: Monatschr. f. Geburtsh. u. Gynäk. **62**:297, 1922.
9. Stübler, E.: Monatschr. f. Geburtsh. u. Gynäk. **62**:173 (March) 1923.

In carcinoma of the fallopian tubes, expansion of the growth follows the line of least resistance, i. e., toward the lumen and abdominal ostium. The latter usually closes early (according to Doran [10]), while the uterine end more commonly remains patent. The possibility of dissemination of the growth is then threefold: First, by rupture of the tube, favored by the thinness of its walls or extension through them. Second, by the lymph stream—this, in itself, affords a multiple outlet, one in the direction of the superior lumbar giving rise to carcinoma of the body of the uterus, another in the direction of the external iliac, hypogastric and sacral glands which may produce carcinoma of the cervix, while a third outlet follows the lymphatic drainage of ovary and fundus uteri, ascending to slightly below the hilum of the kidney, where they curve sharply downward and terminate in the juxta-aortic glands of the corresponding side. The third mode of dissemination is growth by contiguity through the uterine end of the tube with implantation metastasis of the endometrium, or involvement of the ovary by extension through the fimbriated end. Many authors make no mention of these points or only indefinitely. Several mention that the uterine end, for varying distances, was free from growth or apparently normal. Four (Thaler,[11] Boxer,[12] Ries [13] and Müller [14]) note that the uterine portion was concerned in the growth, either being filled with the tumor or having nodular papillary masses. In two cases (Fabozzi,[15] von Franque [16]) there was a small, pedunculated carcinomatous nodule in the uterus just beneath or close to the orifice of the tube, showing the possibility of infection in patent uterine ostia, although, unfortunately, in neither of these cases was the condition of the isthmus described. Bland-Sutton [17] described a case with a dilated and obstructed tube, filled with a soft cancerous mass, which could be traced along the tube in its course through the uterine wall, although the endometrium was not infected. Von Franque [18] reports another case in which the endometrium was healthy although the uterine lymphatic vessels were plugged with cancer cells. Schenck [19] notes a hypertrophy of the epithelium in the uterine end, suggesting beginning carcinoma.

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10. Doran, A.: Brit. M. J. **1**:958, 1888.

11. Thaler, H.: Zentralbl. f. Gynäk. **44**:576, 1920.

12. Boxer, S.: Monatschr. f. Geburtsh. u. Gynäk. **30**:549-570, 1909.

13. Ries, Emil: Primary Papilloma and Primary Carcinoma of the Fallopian Tube, J. A. M. A. **28**:962-968 (May 22) 1897.

14. Müller: Ztschr. f. Geburtsh. u. Gynäk. **58**:96, 1902.

15. Fabozzi: Arch. ital. di. ginec. **5**:125, 1902.

16. Von Franque: Verhandl. d. deutsch. Gesellsch. f. Gynäk. Congress **9**:606, 1901.

17. Bland-Sutton: Clin. J. **24**:4, 1904.

18. Von Franque: Monatschr. f. Geburtsh. u. Gynäk. **22**:152, 1905.

19. Schenck, B. R.: Detroit M. J. **5**:51-53, 1905-1906.

These various modes of transmission show the importance of complete extirpation of all pelvic organs if a cure is to be effected. Lipschütz [20] feels the prognosis is more unfavorable than with carcinoma of any other genital organ. In 1914, he compiled 144 cases (twenty-two of which were doubtful), and only four of these patients were alive after five years. We have been able to collect from the literature only 133 operative cases of undoubted primary carcinoma of the fallopian tubes. It is difficult to determine, with any degree of accuracy, the mortality or the percentage of cures, for the cases have been reported

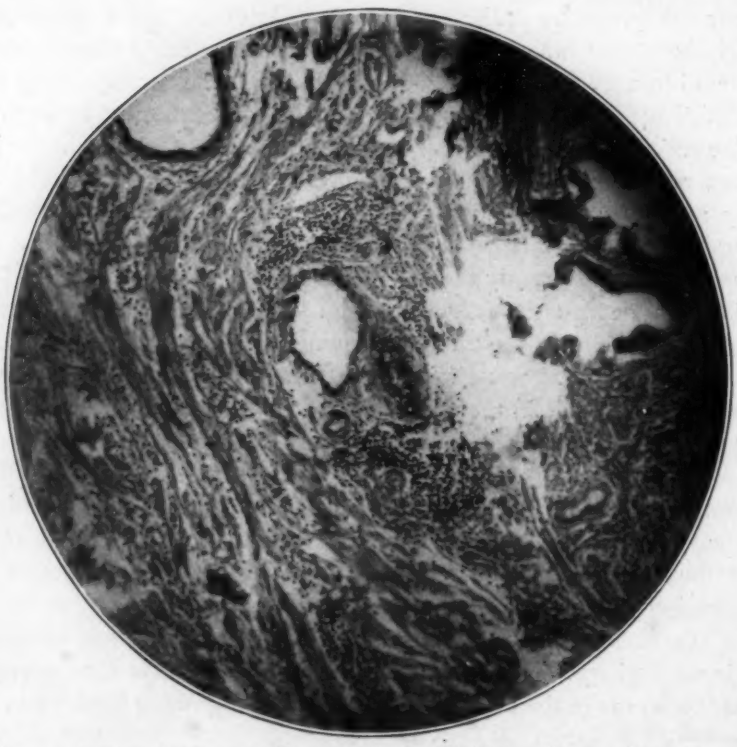

Fig. 4.—Section from ampulla showing epithelial cells in gland formation deep in wall but well inside serosa; round cell infiltration.

as recovered during convalescence, a few months later, when trace of them had been lost, and up to seven years after operation. Including in "deaths" all cases showing postoperative recurrence, we find the mortality to be 48.1 per cent. (64 deaths). This figure is improved, however, if we divide the cases into those having incomplete removal of the pelvic organs, 59.8 per cent., and those with complete removal, 40.2 per cent. In the former, there are eighty cases with forty-five deaths,

20. Lipschütz, K.: Monatschr. f. Geburtsh. u. Gynäk. **39**:33-45, 1914.

a percentage of 56.2, forty-three of those forty-five patients having other organs involved at the time of operation. Of the fifty-three complete removals twenty-one had visible carcinomatous involvement in the pelvis. Eighteen died, giving a mortality of 35.8 per cent. Both the latter figures would undoubtedly be raised had all cases been reported later, but would probably not affect materially the rather striking difference in mortality in favor of the total extirpation of all pelvic organs. Complete removal has been advised by various authors (Norris,[1] Cum-

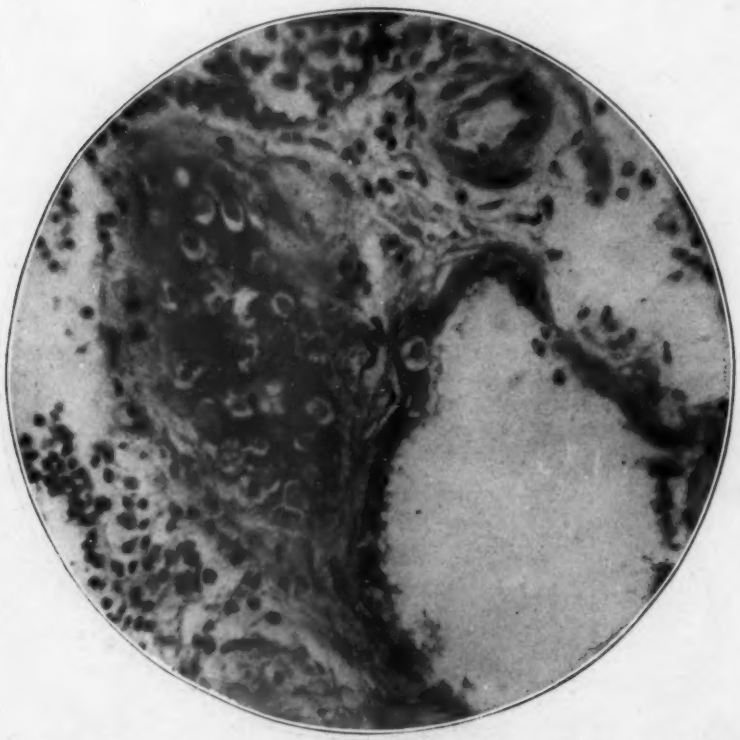

Fig. 5.—High power photomicrograph of central group of epithelial cells in Figure 4; vacuolation.

ston [21]), but it seems as though insufficient emphasis had been laid on the approach. Abdominal rather than vaginal section should be the operation of choice preferably in every woman, for it permits the full inspection of the pelvis and does not delay materially the time of convalescence nor prolong disability; most certainly in all women who have reached the cancer age, and yet three of the patients with primary carcinoma of the fallopian tubes were under 30 (Norris' patient being

21. Cumston, C. G.: Internat. Clin. **24**:218-221, 1914.

27, Hare's [22] 29, and our own, 25), none of whom would ordinarily be considered within the cancer period.

Although the ovary is frequently involved, particularly in cases in which adhesions exist between it and the fallopian tubes, the invasion is more easily recognized grossly, and the possibility of recurrence by leaving it in situ does not seem to be so great as is offered by nonremoval of the uterus, which may appear normal macroscopically and yet be malignant microscopically. This is well illustrated by our case, in which it

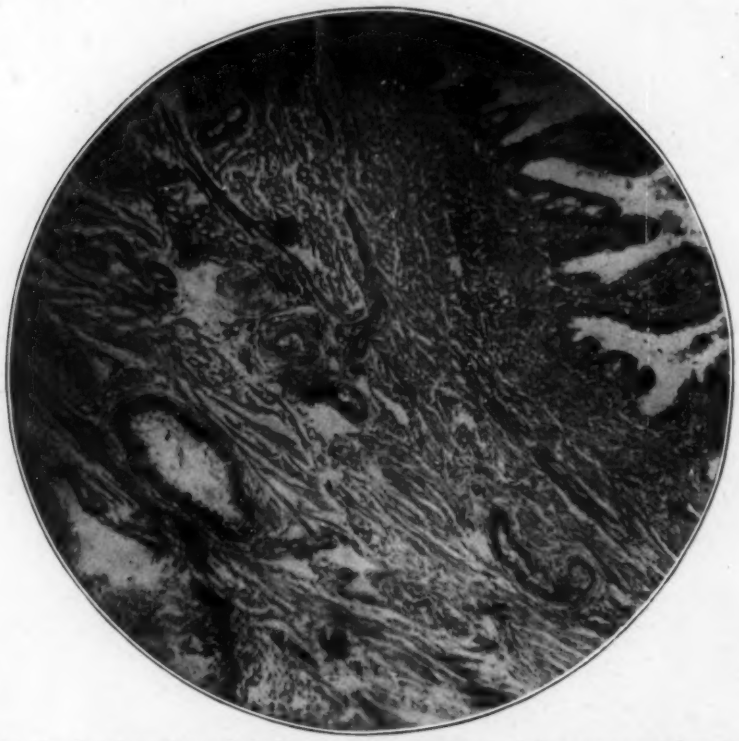

Fig. 6.—Section through isthmus of tube; upper right: mucosa; lower left: group of epithelial cells in gland formation. At no place had epithelial cells penetrated to the peritoneal coat.

appeared of normal size at both operations, yet showed evidence of involvement on microscopic examination. In eleven cases, the uterus was described as invaded, infected, or showing metastatic or secondary deposits on the wall of the serous coat (Danel,[23] Fabricius,[24] Fehling,[25]

22. Hare: Boston M. & S. J. **152**:606, 1905.
23. Danel: J. d. sc. méd. de Lille **11**:121, 1907.
24. Fabricius: Wien. klin. Wchnschr., No. 49, p. 1230, 1899.
25. Fehling: Lehrbuch- der Frauen Krankheiten, Ed. 3, p. 306.

Doran,[26] Kehrer,[7] Lecène,[27] Doran and Taggart,[28] Barris,[29] Koenig,[30] Boxer [12] and Hillebrand [31]).

In only a few of the cases reported has the uterus been microscopically examined for the presence of metastasis or invasion, and in only the minority of these has any evidence of involvement been found. This, in itself, is of interest in view of the history of many cases, i. e., cramp-like pain in the lower part of the abdomen, relieved following a watery,

Fig. 7.—Section through uterine cornu; numerous irregular spaces lined by vacuolated columnar epithelium in muscular wall.

frequently blood stained discharge from the vagina. Lipschütz considers this to be the result of distention of the tube, temporarily blocked at the uterine end, relieved by the escape of the contained fluid through the

26. Doran, A. G.: J. Obst. & Gynec. Brit. Emp., London **1**:285-307, 1904; ibid. **17**:123, 1910.

27. Lecène, P.: Ann. de gynéc. et d'obst., Paris **6**:418-423, 1909.

28. Doran, A. H. G.: J. Obst. & Gynec. Brit. Emp., London **17**:1, 1910.

29. Barris, J. D.: Proc. Roy. Soc. Med., London **13**:209 (Section V, Obst. & Gynec.) 1919-1920.

30. Koenig: Gynackol. Helvet. **12**:1-3, 1912.

31. Hillebrand, E.: Monatschr. f. Geburtsh. u. Gynäk. **57**:72 (Feb.) 1922.

uterus and vagina. One might suppose that many malignant cells could be readily swept into the uterus by the mechanical relief of pressure, and yet in only a small percentage of these cases was there endometrial involvement reported (Westermark and Quensel,[32] Novy, von Franque and Zangemeister,[33] Fabozzi and von Franque). One case of uterine involvement by way of the lymphatics with a normal mucosa has been reported by von Franque, while Bland-Sutton describes a case with free endometrium but a tubal canal through the cornu plugged with carcinoma cells.

In our own case, the true diagnosis, as has been pointed out, was entirely unsuspected at operation, even though there was free blood-stained fluid in the peritoneal cavity and absence of adhesions around the tubes, and a firmer consistency of the excised tubes noted than is usually found in pyosalpinx. Incision of the tubes after the abdomen had been closed showed grossly its papillomatous contents and the patency of the uterine ends, while histologic examination showed the malignant change in the growth, and the fact that at the uterine end a few glandular elements had penetrated into the wall of the tube. Even though the histologic study of the tumor showed the growth to be only mildly malignant, the presence of epithelial cells in the tube wall at the uterine end indicated the possibility of their presence in the uterine cornua. Because of the immediate freedom from previous complaint following the first operation, permission for a second operation was not granted until almost six months later, although the patient had consented to one radium treatment of 100 mg. of radium implanted in the fundus. At the second operation, six months after the first, a supravaginal hysterectomy was performed, the ovaries being left in situ. Several factors decided this conservative procedure: First, the abdominal ends of the tubes were closed and no adhesions existed between them and the ovaries, at the first operation, and, at the second operation, they were not enlarged; second, the absence of any glandular enlargement or other involvement; third, the fact that she had already had one radium treatment, and, fourth, the age of the patient. A supravaginal operation rather than panhysterectomy seemed to be the operation of choice, for then the cervix could be utilized for postoperative implantation of radium.

SUMMARY

A case of primary bilateral carcinoma (malignant papilloma) of the fallopian tubes is reported, this being the youngest patient on record (25 years).

32. Westermark and Guensel: Nord. med. Ark. **24**, 1892.

33. Zangmeister: Brüns Beiträge z. klin. Chir. **34**:96, 1902.

The presence of blood stained fluid in the peritoneal cavity, heretofore unmentioned in the disease, is offered as an additional sign of malignancy of the fallopian tubes.

Although the incidence of primary carcinoma of the fallopian tubes is quite low, incision immediately on its removal would show the true nature of the condition and allow complete extirpation of all pelvic organs, with the possible exception of the cervix. Supravaginal hysterectomy is recommended, since it offers a better prognosis in a disease having a mortality of 50 per cent., a rate influenced by the many avenues of dissemination present in the tube, while the preservation of the cervix would permit subsequent radium implantation.

SPRENGEL'S DEFORMITY

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SAN FRANCISCO

The patient was a boy, aged 11 years, who was seen at the Stanford Clinic. The parents said that he had been born with the left shoulder higher than the right, and that the deformity had steadily grown worse. They had noticed a curvature of the spine. No pain other than an occasional dull ache had been felt.

Examination showed a very high left scapula, very close to the spine, with a lateral curvature in the cervical region, and an asymmetry of the face. The scapula evidently was attached at its superior angle, and at this point there was a distinct prominence. A bony growth ran from it to the spine. The elevation amounted to about 10 cm. The motions of the head were limited.

The boy was photographed. Roentgenograms showed the high scapula and a bony growth like a short rib running from it to the spine at about the level of the sixth or seventh cervical. The cervical spine was curved, and the lower cervical vertebrae showed various developmental abnormalities, sufficient in themselves to cause the curvature even in the absence of the scapular deformity. They were described as a failure of union of the arches of the last two cervical and the first thoracic vertebrae and a transverse division of the second cervical body.

Dec. 17, 1919, an operation was performed. The incision was curved, exposing the base of the scapular spine and the bony growth attached to it. The periosteum of the growth was slit; then the growth was bared by subperiosteal dissection. It consisted of bone, with cartilage at its scapular end. Between it and the scapula was a joint with very little motion. It ran medially and cephalad to the spine, where it articulated with the spinous process of a cervical vertebra. A small process on its caudate aspect articulated with the spinous process of the vertebra next below it. The articulations were separated, and the bone was removed. It appeared like a small, thick rib. The periosteal tube was then sectioned transversely about its middle, and its lateral part was sewn back over the scapula to prevent the reformation of the growth. The medial portion was dissected out. The wound was closed with catgut in layers.

No motion was demonstrated between this "rib" and the spine. The articulation was very rigid. The limited amount of motion in the scapula evidently took place at the joint between the "rib" and the scapula.

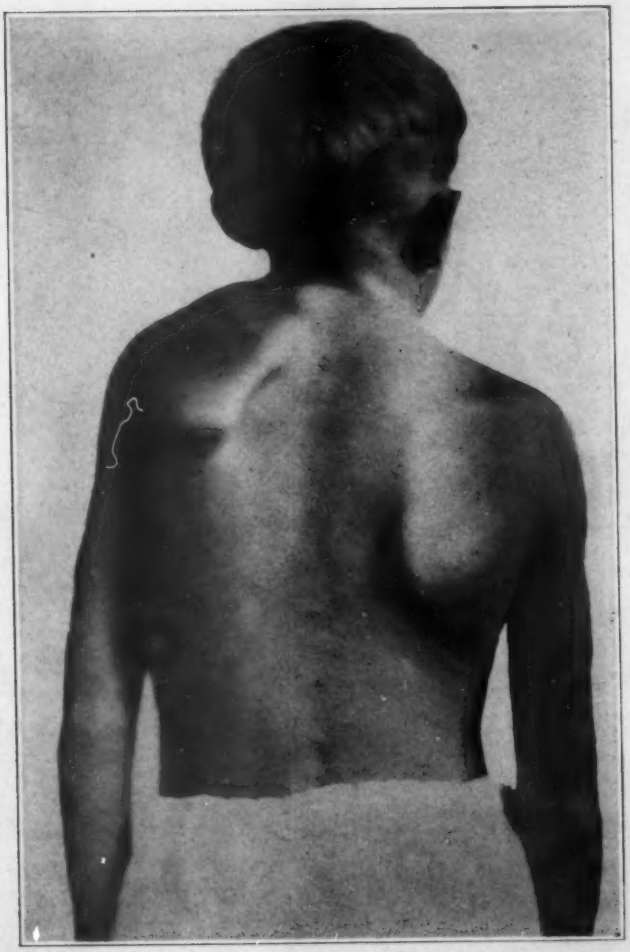

Fig. 1.—Patient before operation.

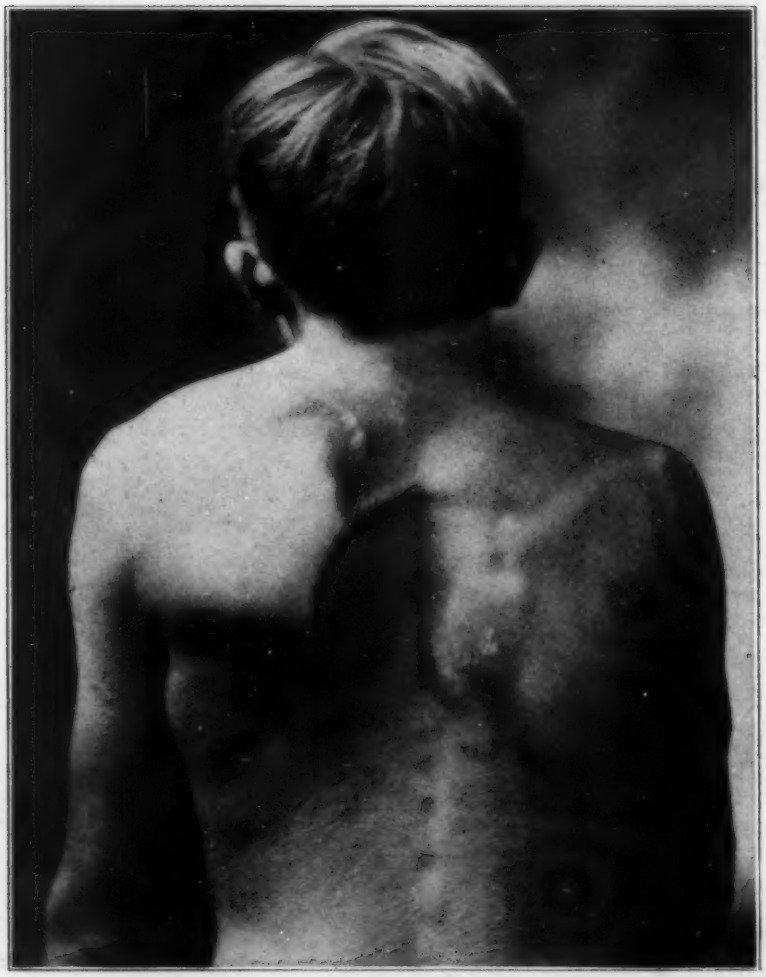

Fig. 2.—Patient four and one-half years after operation.

The patient was last seen about sixteen months after the operation. At that time, the deformity was somewhat better but still was quite severe. Photographs taken four and one-half years after operation show that it is still present. Unfortunately, an examination of the patient to determine function cannot be secured.

Fig. 3.—Spine four and one-half years after operation.

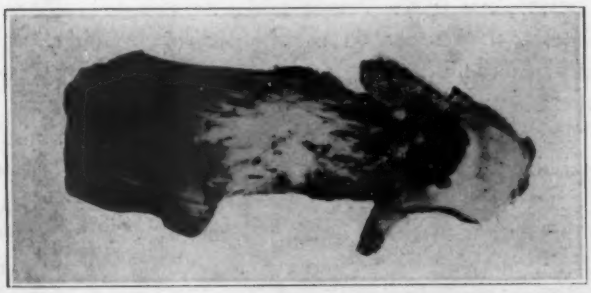

Fig. 4.—Costal element, anterior surface; right: cartilage for articulation with the scapula.

In a case like this, with well marked spinal deformity, any operation on the soft structures of the neck, with the object of depressing the scapula, would almost certainly be futile. The high shoulder is manifestly caused by the spinal curvature.

TUMORS OF THE SMALL INTESTINE

WITH ESPECIAL REFERENCE TO THE LYMPHOID CELL TUMORS *

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This paper is based on a careful study of nine cases of submucous lymphoid cell tumor of the small intestine which have been diagnosed at the Surgical Pathological Laboratory of Johns Hopkins Hospital as round cell sarcoma or chronic inflammatory tumor. The report also includes three cases of similar tumors in the large intestine. For the purpose of comparison, four cases of tuberculosis, three of carcinoma, three of adenoma and one of myxofibroma are also reported.

The name chronic inflammatory tumor has been used by various pathologists to designate various lesions which are on the borderline between true neoplasms and chronic inflammatory tissue. Osteitis fibrosa, giant cell tumor of the bone, xanthoma and Hodgkins' disease of the lymph glands belong to this category. The term granulation tissue tumor is also applied to these lesions.

The histologic study of the nine tumors of the small intestine and three of the colon does not justify their division into separate groups. They are all round cell tumors apparently originating from submucous lymphoid nodules, and, in view of the fact that they are assuredly not tumors of connective tissue origin and that the cells do not resemble endothelial cells, they must be regarded as lymphoid tumors. They have appeared in the literature under various names, a few of which are lymphosarcoma, lymphocytoma, round cell sarcoma, intestinal Hodgkin's disease, granulomatous pseudoleukemia, chronic inflammatory tumor, lymphoblastoma and lymphoid granulation tumor. Crowther [1] in 1913 reviewed the literature and compiled 122 cases, and later, in 1919, Graves [2] extended the compilation to 249. The latter noted the confusion of the nomenclature in connection with these round cell tumors and pleaded that they all be called lymphoblastoma, which, quoting Mallory, means "a tumor of mesenchymal origin of which the cells tend to differentiate into lymphocytes, that is, into cells of the lymphocyte series."

The essential features in the histology of these tumors are as follows: 1. There is an infiltrative new growth composed of round

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* From the Surgical Pathological Laboratory of the Johns Hopkins Hospital.

1. Crowther: Clin. chir., Milan, **21**:2107, 1913.
2. Graves, S.: J. M. Res. **40**:415 (Sept.) 1919.

cells usually somewhat larger than the lymphoid cell, with some variations in size and shape depending on the rate of growth. 2. The nuclei are large and vesicular, usually containing one nucleolus. 3. Larger cells, occasionally with two or three nuclei, are sometimes present. 4. Mitoses are common. 5. The stroma consists of a fine connective tissue network which may be very vascular. 6. The growth starts in the submucosa and invades the mucosa on one side and the muscularis on the other. The mucous membrane quickly becomes necrotic; the epithelium is desquamated, and a raw ulcer covered with débris remains. In some cases, the muscularis becomes involved and is replaced by tumor tissue, but in none of the cases of this series was the serosa broken through.

Lymphoid tumors have frequently been confused with inflammatory processes, and there must be many borderline cases. This group, however, must be classed as definite new growths. A few fibrosed tubercles with giant cells were found in the mesenteric glands of one of the patients, but this must have been a coincidence, since the lesion evidently was of many years' standing. In none of the primary tumors was there even a resemblance of a tubercle or the presence of a multinucleated giant cell of the type that we expect to find in tuberculosis. Only one patient had a positive Wassermann reaction, and the absence of other lesions of apparent syphilitic origin in the other cases suffices to exclude syphilis as an etiologic factor.

Clinically, these twelve cases present the following interesting features:

Race.—Nine cases, or 75 per cent., were in white people. The 25 per cent. in negroes probably corresponds to the normal ratio of the colored to the white population in the districts from which these cases were reported.

Sex.—Eight were in males and four in females. The two to one ratio in favor of males is in agreement with previous reports in the literature.

Age.—The twelve patients were between 5 and 60 years of age. Five cases, or 42 per cent., occurred in the first decade of life. The remaining seven were evenly distributed through the next five decades.

Number of Tumors.—In nine cases, or 75 per cent., the lesion was single. Two patients had two tumors each, and one patient had ten. It was difficult to determine in these multiple lesions whether all the tumors were primary or whether they were implantations from one primary focus.

Location of the Tumors.—In nine cases, or 75 per cent., the tumors were in the small intestine, and all of these occurred in the lower portion of the ileum. In three cases, or 25 per cent., the tumors were in

the large intestine, but two of these were in the cecum close to the ileocecal valve. Therefore, eleven out of the twelve cases were in the ileocecal region. The remaining one was in the sigmoid. This is in conformity with the observation of other observers, with the exception of Libman,[3] who found the duodenum as common a site for sarcoma as the ileum.

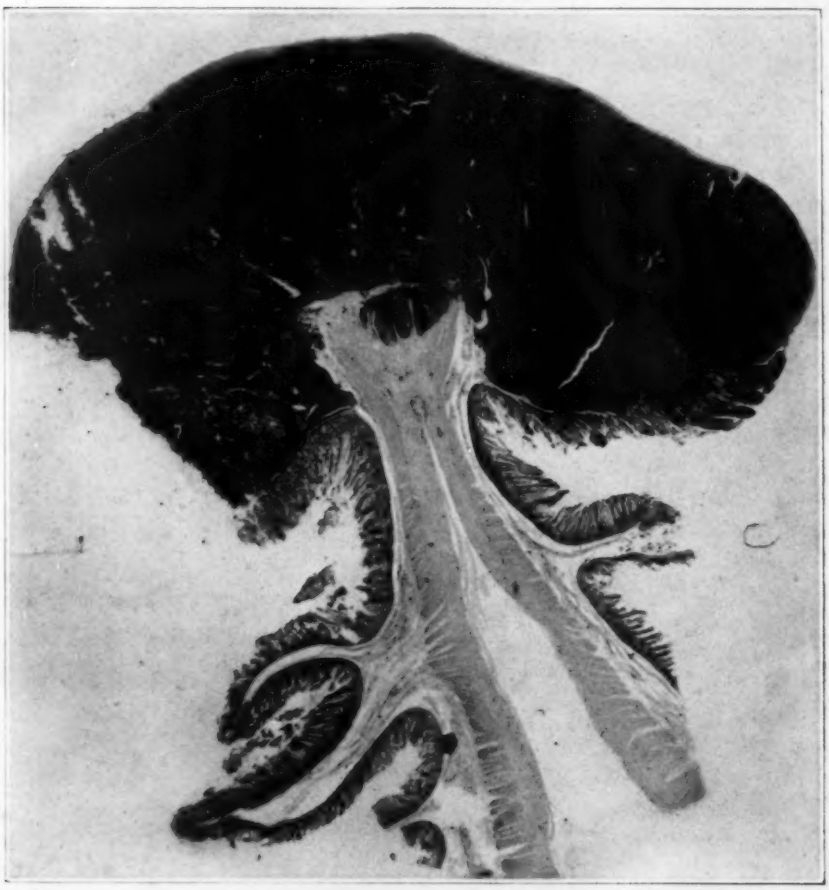

Fig. 1 (Case 7).—One of ten polypoid tumors in ileum causing multiple intussusceptions, as seen under low power; below: pedicle with normal mucous membrane; above: subperitoneal area of lymphoid tissue (either a chronic inflammatory tumor or a submucous lymphoblastoma).

Form of Growth.—The tumor was annular in character in seven cases, or 60 per cent. In four cases, or 33 per cent., the tumors were localized outgrowths from the intestinal wall of a polypoid character,

3. Libman, E.: Am. J. M. Sc. **120**:309, 1900.

some having broader bases of attachment than others. One patient had a small polypoid tumor in the ascending colon in addition to a large annular tumor at the ileocecal valve. All the patients with multiple lesions had polypoid growths. It must be said that the tumors described as polypoid should more properly be called fungoid.

Intussusception.—Six cases, or 50 per cent., were complicated by intussusception, only two of which were in patients under 10 years of age. All four patients with polypoid tumors, 100 per cent., had intussusception. Two cases out of seven with annular growths were also thus complicated, that is, 28 per cent.

Stenosis.—Ten cases, or 83 per cent., presented stenosis of the intestinal lumen. The two cases which did not show stenosis had polypoid growths. In other words, all the cases with annular tumors and two with polypoid growths gave rise to constriction of the lumen. This observation also differs from that of Libman,[3] who asserts that sarcoma often causes dilatation and very rarely stenosis.

Indication for Operation and Preoperative Diagnosis.—In view of the fact that every case had either intussusception or stenosis, the indication for operation in every case was intestinal obstruction, either acute or chronic. Beyond this, the diagnosis cannot be more definitely made, except in the cases with palpable tumors of more than a few days' duration in which a neoplasm is naturally thought of. One patient was operated on for a gynecologic condition, but, on reviewing the history, it is evident that the symptoms were those of a chronic obstipation. Another case was diagnosed appendicular abscess, but this also presented signs of obstruction.

Blood Picture and Relation to Lymphatic Leukemia.—None of these cases had any relation to leukemia. Secondary anemia of a mild degree was a frequent occurrence.

END-RESULTS

To the high standard of operative technic of the surgeons must be attributed the operative mortality of only one in these twelve cases. Even this death cannot fairly be credited to the operation, because the patient died sixteen days later, and the necropsy showed pulmonary embolism as the cause of death, while the wounds of the intestines were perfectly healed. Taking into consideration that resection was done in ten of these cases, in some of which the obstruction was acute, the results are most gratifying. Two patients were operated on within the last six months, and are living and well. Of the remaining ten, four patients, or 40 per cent., are living and free from recurrence from one and one-half to six years after operation. Three of these have remained well more than five years. Two patients are known to have died of recurrence, both between two and three months after

operation. One of these was a child 6½ years old, and the other a woman of 45. The former had a polypoid growth which was excised through an enterostomy, and the latter had a resection done. The microscopic pictures of these tumors do not differ from those of the cured cases, and every effort to differentiate them, with reference either

Fig. 2 (Case 8).—Tumor, which was situated in the ileum, in the gross in lower portion of picture. Resection of the ileum and the cecum because of intussception was done. The microscopic appearance was not unlike that shown in Figure 1.

to the amount and character of the cellular content, infiltrative tendency, presence of mitoses or vascularity has failed. Two of the patients have not been heard from.

Both Baltzer [4] and Libman [3] give the prognosis in sarcoma of the intestine as invariably and rapidly fatal, but Miller,[5] in a recent article, is more optimistic, and cites patients living from two to eight years after operation.

IMPRESSIONS ON THE ETIOLOGY AND MALIGNANCY

The preponderance of these tumors in the ileocecal region, where lymph nodules are normally most numerous, the origin in the submucosa and, also, the large number of cases occurring in the first decade point strongly to an embryonic origin. They may be compared to the carcinoma of the appendix, which is known as a benign tumor. It seems wise to call them all submucous lymphoblastomas, and to

Fig. 3 (Case 10).—Longitudinal section through tumor at ileocecal junction; resection for intussusception was done. The microscopic picture suggested round cell sarcoma.

assume that the lymphosarcoma of the small intestine is the same tumor which has taken on malignant characteristics.

REPORT OF CASES

NINE CASES IN THE SMALL INTESTINE

Case 1.—A white girl, aged 5, a patient of Dr. Witherspoon of Butte, Mont., had symptoms of constipation for one year. The operation was resection. Microscopic sections showed round cell sarcoma of the intestine. The patient died three months after the operation.

Case 2.—A white boy, aged 6½, had a first operation for acute intestinal obstruction. The intussusception of the ileum into the cecum was easily

4. Baltzer, A.: Arch. f. klin. Chir. **14**:717, 1873.
5. Miller, C. J.: Surg., Gynec. & Obst. **17**:210, 1913.

reduced. A polypoid tumor the size of a man's thumb was found in the lumen of the ileum; this was excised without resection of the bowel. After the operation, there was vomiting at periods, with black stools. The tumor was growing larger. A second operation, two months later, was performed by Dr. Bloodgood. There was a growth in the intestine with extensive metastases in the parietal peritoneum. The condition was deemed inoperable. Small bits of metastatic tumor removed showed infiltration of connective tissue with a tumor composed of medium sized round and polygonal cells with scanty protoplasm arranged in irregular cords and masses. There were many mitoses. The diagnosis was round cell sarcoma, possibly lymphosarcoma. The patient was given radium treatment, and died.

Fig. 4 (Case 4).—Gross specimen showing annular tumor producing annular constriction; the microscopic diagnosis was chronic inflammatory tumor (Figs. 5 and 6); resection was done.

Case 3.—A negro, aged 60, had chronic constipation for six months, accompanied by vomiting, loss of weight and anemia. The Wassermann reaction was negative. At operation, performed by Dr. Reid at Johns Hopkins Hospital, an annular tumor the size of an English walnut was found in the ileum 4 feet (121.9 cm.) proximal to the ileocecal valve which was causing stenosis. The regional lymph glands were enlarged but soft. Resection and anastomosis were done. Sections of the tumor showed a very vascular lymphoid granulation tissue infiltrating the submucosa and muscularis. The cells were somewhat larger than normal lymphocytes, but very uniform in size and shape. The microscopic

diagnosis was chronic inflammatory tumor. The patient was discharged from the hospital well, but has not been heard from since.

Case 4.—A white boy, aged 5, a patient of Dr. E. H. Teeter of Jacksonville, Fla., was operated on for acute intestinal obstruction. An annular tumor was found in the ileum almost completely occluding the lumen. A gross specimen showed ulceration of the mucosa and thickening of the submucous layers by means of a pearly white growth invading both the submucosa and the muscularis. It looked and felt like scirrhous cancer. Sections showed a very cellular tumor infiltrating the mucosa and the submucosa, in places invading the muscularis

Fig. 5 (Case 4).—Right: remains of mucous membrane; left: submucous chronic inflammatory tumor, or lymphoblastoma (gross specimen in Figure 4). Comparison should be made with Figure 1. In Figure 1, the tumor is a polypoid growth; in Figure 4, it is an annular constricting growth.

and the subserous tissue. The tumor was composed of medium sized round and polygonal cells of lymphoid type, with fairly abundant protoplasm and vesicular nuclei. There were numerous mitotic figures. The diagnosis was chronic inflammatory tumor. The patient has been well for three and one-half years.

Case 5.—A negro, aged 18, a patient of Dr. G. J. Winthrop of Mobile, Ala., was operated on for acute intestinal obstruction and intussusception. At the

apex of the intussusception in the terminal portion of the ileum were seen two sessile tumors about 2 inches (5 cm.) apart. Two feet of gangrenous intestine were resected. A gross specimen showed these tumors, sections of which, however, did not show morphology on account of gangrene. The adjacent intestinal wall showed vascular granulation tissue with a fairly marked lymphoid cell infiltration. The diagnosis was chronic inflammatory tumor. There was immediate recovery. The patient was lost sight of.

CASE 6.—A white woman, aged 31, a patient of Dr. G. T. Tyler of Greenville, N. C., had chronic indigestion, constipation and vague abdominal pain for

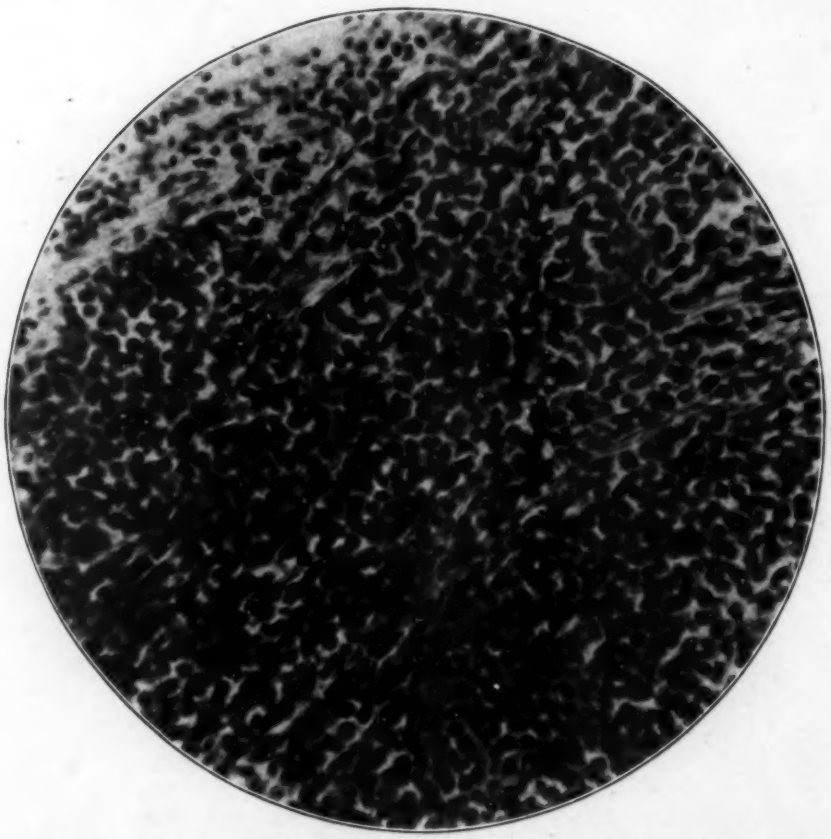

Fig. 6 (Case 4).—Specimen in case illustrated in Figures 4 and 5 as seen under high power, showing the difficulty of distinguishing a chronic inflammatory tumor from a lymphosarcoma, Hodgkins disease or ordinary round cell sarcoma.

eight or nine years. The Wassermann reaction was +++. The right tube and ovary and appendix were removed. Accidentally an annular tumor of the ileum almost obstructing the lumen was discovered. Resectin and anastomosis were done. Sections showed a new growth composed of small round cells infiltrating the entire thickness of the intestinal wall and invading the fat of the mesentery. The diagnosis was chronic inflammatory tumor. The patient was living and well after six months.

CASE 7.—A negro, aged 24, a patient of Dr. G. J. Winthrop of Mobile, Ala., was operated on for acute intestinal obstruction. Three separate intussusceptions with ten polypoid tumors were found in the ileum. Three portions of the intestine containing tumors were resected. The patient died sixteen days after the operation from pulmonary embolism. Sections showed a new growth composed of medium sized round cells invading and destroying the mucous membrane. The diagnosis was chronic inflammatory tumor or sarcoma.

CASE 8.—A white man, aged 39, a patient of Dr. J. M. T. Finney, had a history of pain in the right lower quadrant of the abdomen and chronic constipation of several weeks' duration. Other symptoms were blood in the stools, vomiting and loss of weight. At operation, an annular tumor, measuring 5 by 6 by 4 cm., was found in the ileum which had invaginated into the cecum. The

Fig. 7 (Case 9).—Gross specimen; larger lesion at ileocecal valve and second, smaller tumor to the right in the cecum; microscopically diagnosed as a chronic inflammatory tumor or lymphoblastoma. This tumor produced constriction with obstruction. Comparison should be made with Figure 4.

lumen narrowed down to 0.5 cm. in diameter. The glands showed gross involvement. The lower end of the ileum and the cecum were resected. The glands were not completely removed. Sections showed necrotic mucous membrane under which was a zone composed of connective tissue stroma, in meshes of which were collections of irregularly shaped cells, round and polygonal. The size of the cells varied from that of a small lymphocyte to large mononuclear cells several times larger. Many mitotic figures were seen. The glands showed similar growths. One gland showed the presence of a few fibrosed tubercles with giant cells, but the lesion in the intestine certainly was not tuberculous. The diagnosis was chronic inflammatory tumor or sarcoma. The patient was well and in perfect health eight and one-half years after operation.

CASE 9.—A white girl, aged 9, with a history of pain in the right side and vomiting for six months, was operated on in Richmond, Va., five months before this operation; her condition was considered inoperable and the wound was closed when the surgeon discovered tumor on exploration. At Johns Hopkins Hospital she received a diagnosis of appendicular abscess, for which condition she was operated on. At operation by Dr. Reid, a large mass was found in the region of the cecum, which necessitated an extensive resection of the ileum, cecum and greater portion of the ascending colon. A gross specimen showed an infiltrating tumor involving both the terminal portion of the ileum and the cecum for a distance of about 6 inches (15.2 cm.). The growth extended completely around the wall of the bowel and caused a narrowing of the lumen. In places, the intestinal wall was over an inch (2.5 cm.) thick. A section showed a fairly firm, grayish white tumor, resembling lymphosarcoma. In the ascending colon, some distance away from the main mass, there was a mushroom shaped tumor, the size of a twenty-five cent piece, of the polypoid type, projecting from the wall. Sections showed a very cellular tumor invading all the coats of the intestine and destroying the mucosa. The cells were of the lymphoid type, somewhat larger than

Fig. 8 (Case 9).—Gross section through larger tumor shown in Figure 7; surface suggests lymphosarcoma (microscopic appearance in Figure 9).

the small lymphocyte, and there seemed to be a slight tendency toward tubular arrangement. Mitoses were frequent, and there were many larger cells with two or three nuclei. The smaller polypoid growth showed an identical structure, but the tumor was essentially a submucous nodule, and was sharply limited by the muscularis. The mucous membrane also showed some ulceration. The diagnosis was chronic inflammatory tumor or sarcoma. The patient was discharged from the hospital one month after the operation, well.

THREE CASES IN THE LARGE INTESTINE

CASE 10.—A white boy, aged 10, a patient of Dr. Stewart D. Brown of Royston, Ga., had abdominal pain and colic for one year. The pain and tumor on the left side of the abdomen were always relieved by enemas. Acute obstruction with intussusception was the immediate indication for operation. At operation, a tumor was found in ileocecal region causing invagination of the ileum into the ascending colon. Resection of the ileum and the cecum was done. A gross specimen showed tumor the size of a lemon growing and protruding from the wall of the cecum between the base of the appendix and the

ileocecal valve. The bowel showed constriction, admitting only the little finger. The tumor had a broad base which, however, did not reach the peritoneal coat of the bowel. The cut surface was grayish-yellow, firm and of uniform consistency. The mucosa showed extensive ulceration. Microscopic sections showed a tumor composed of round cells slightly larger than the lymphocyte, growing in masses supported by a scanty connective tissue stroma. The tumor did not infiltrate and was sharply limited by the muscularis. The diagnosis was sarcoma. The patient is well seven years after operation.

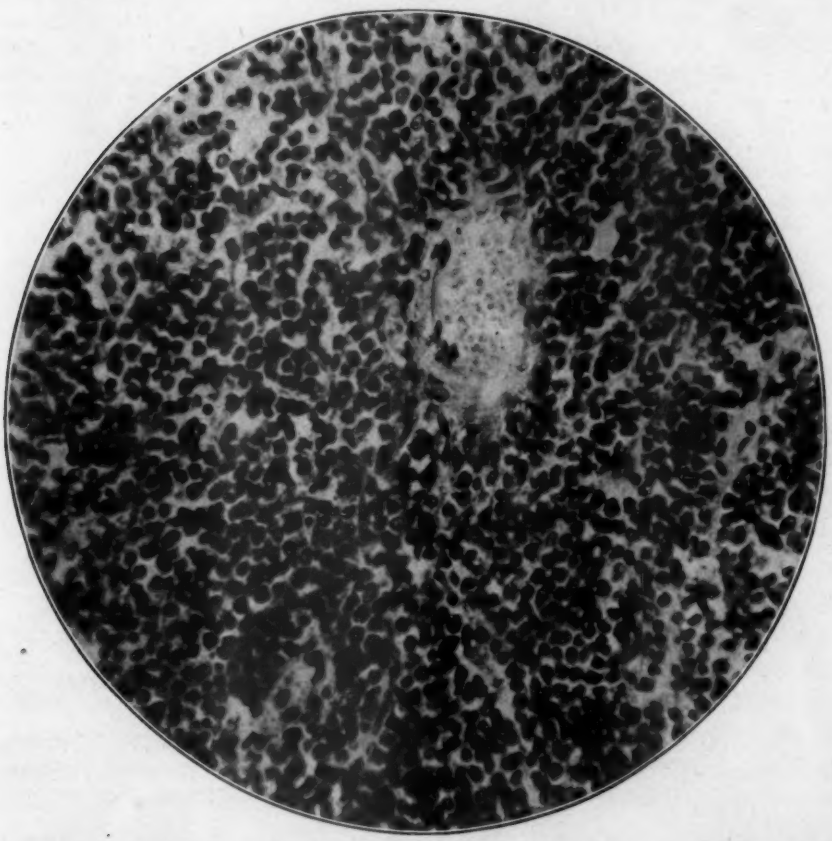

Fig. 9 (Case 9).—Tumor shown in Figures 7 and 8 as seen under high power. Comparison should be made with Figure 6.

Case 11.—A white woman, aged 45, a patient of Dr. C. N. Callander of Fargo, N. D., had pain and tenderness in the right groin of ten days' standing. There were no symptoms of obstruction. At operation, a tumor mass was found in the cecum and a resection of the cecum with 2 feet (60.9 cm.) of the ileum was done. A gross specimen showed an annular growth the size of an orange in the wall of the cecum beginning at the ileocecal valve. The lumen was very much constricted. Microscopic sections showed a small round cell sarcoma with cells of the lymphoid type arranged in small and large irregular masses separated by a very fine connective tissue stroma. A tumor was infiltrat-

ing the muscular layers, but the peritoneal coat of the intestine showed no involvement. The diagnosis was sarcoma. The patient died of rapid extension of the disease two and one-half months after operation.

CASE 12.—A white man, aged 53, a patient of Dr. Tinker, Ithaca, N. Y., had obstinate constipation for several months. There was a mass in the sigmoid causing obstruction. Resection was done. A gross specimen consisted of a piece of the large intestine with very thick walls which felt stony and hard. On section, the tumor was dense, fibrous and rather pearly in appearance. Microscopic sections showed a tumor composed of moderately large round cells of the lymphoid type growing in a connective tissue stroma and infiltrating the submucous and muscular layers. The mucosa was intact. The diagnosis was chronic inflammatory tumor. The patient was living and well five years after the operation.

Fig. 10 (Case 19).—Carcinoma (adenocarcinoma type) of wall of jejunum, producing constriction similar to that shown in Figure 4. There were symptoms of chronic obstruction; resection with the involved glands was done.

INFLAMMATORY LESIONS OF THE INTESTINE SIMULATING NEW GROWTHS

There are definitely inflammatory lesions of the intestine which clinically and at operation cannot be differentiated from new growths. Jones and Eisenberg,[6] in a recent article on "Inflammatory Neoplasms of the Intestine Simulating Malignancy," cited several cases in which the pathology was proved to be tumor formation consisting of excessive overgrowth of connective tissue. The etiologic factors are impossible to

6. Jones, N. M., and Eisenberg, A. N.: Surg., Gynec. & Obst. **27**:420 (Oct.) 1918.

determine in many of these cases, and the patients who do not show acute obstruction or perforation, as a rule, recover without more than an exploratory operation. Cases of inoperable cancer, particularly of the large intestine and rectum, in which the patients remain well after being given up as hopeless undoubtedly belong to this group. Histologically, there is scar tissue formation with more or less lymphoid cell infiltration, the whole picture being that of a chronic inflammatory reaction which is not easily confused with the lymphoid tumors. The presence of this group of cases is one of the strongest arguments against calling any of the lymphoblastomas chronic inflammatory tumors or lymphoid granulation tumors.

One case of this nature involving the small intestine is here reported.

CASE 13.—A negro, aged 40, had pain around the umbilicus with nausea and vomiting for five months, and secondary anemia. At operation, a contracture of the ileum, 18 inches (45.7 cm.) from the cecum, which had thick and firm walls simulating malignant disease, was found. Many enlarged mesenteric lymph-glands were found. Enterostomy was performed to relieve the obstruction. The patient died six days after the operation. Necropsy showed fibrosis of the intestinal wall due to the presence of a foreign body, which was a vertebra from a small animal—probably a squirrel.

In the large intestine, lesions of this nature are more frequently seen. A large percentage of these result from dysenteric colitis, or proctitis from any cause.

TUBERCULOSIS OF THE SMALL INTESTINE SIMULATING NEW GROWTHS

It is often very difficult and sometimes impossible to differentiate clinically between tuberculosis of the small intestine and neoplasms. Even at operation, a difference in diagnosis between them cannot certainly be made, especially when the tuberculous lesion is a localized and long standing one. Of the four cases reported here, all were in the lower portion of the ileum. All the patients were under 40 years of age. Two of the patients had acute intestinal obstruction. The lesions were multiple in two cases. The growths were annular in three cases, and in the form of slightly raised ulcers in the fourth. None assumed a polypoid or fungoid appearance. Intussusception did not accompany any of these cases. As to ultimate results, one patient died as the result of the operation, and of the remaining three, two died within from two to three years after the operation. One patient is now living, eight years after the operation, but the lesion in her case was a chronic inflammatory or scar tissue tumor rather than active tuberculosis.

CASE 14.—A negress, aged 26, received a clinical diagnosis of intestinal obstruction. At operation, by Dr. G. J. Heuer, at Johns Hopkins Hospital, several annular strictures were found in the lower ileum, one of which caused almost complete stenosis. This portion of the intestine was resected. Sections showed

typical tubercles and giant cells and marked fibrosis in the wall of the intestine. The patient died between two and three years after the operation.

CASE 15.—A white woman, whose age was not given, married, had pain in the right lower quadrant of the abdomen for two weeks. She had suffered from acute intestinal obstruction for twelve hours. A clinical diagnosis of tumor was made. At operation, by Dr. W. A. Fisher, Jr., of Baltimore, a large mass, 6 inches (15.2 cm.) long, causing complete obstruction, was found in the ileum 12 inches (30.4 cm.) from the ileocecal valve. Resection was done. Microscopic sections showed marked fibrosis of the intestinal wall with a diffuse infiltration of lymphocytes and polymorphonuclear leukocytes. The remains of many old tubercles with giant cells were seen. The patient was living and well one year after the operation.

CASE 16.—A white boy, aged 6, had abdominal pain, and a mass could be felt in the right lower quadrant for one month. There was no obstruction. At operation, many indurated ulcers were found in the lower ileum, one of which, near the cecum, was gangrenous and on the point of perforation. Resection and enterostomy were done. Sections showed typical active tuberculosis. The patient died a few days after the operation.

CASE 17.—A white man, aged 38, had blood in the stools and abdominal pain for four years. A tumor was palpable in the right lower quadrant of the abdomen. At operation, a large mass involving the lower end of the ileum was resected. There was no obstruction. Sections showed active tuberculosis. The patient died one and one-half years later.

CARCINOMA OF THE SMALL INTESTINE

The small intestine is the seat of only 3 per cent. of intestinal cancers. The three cases here reported were in men 35 or over. The tumor was single and annular in every case. Two caused stenosis, but there was no intussusception in any of them. Two were in the ileum and one in the jejunum. All resulted in the death of the patient, two from recurrence and one as the result of the operation. Microscopic study showed that two were adenocarcinomas, and that the third one was a carcinoma of the basal cell type. The induration in these tumors helped to differentiate them at operation from the lymphoid tumors, which are more elastic; but the scar tissue tumors and tuberculosis are not easily distinguished from cancer except by microscopic study.

Bunting [7] was the first to recognize the basal cell type of carcinoma in the intestine. He reported one case and compiled six others, in all of which the patients died of other causes. The lateness of the recurrence in the case reported here (Case 18) might mean another primary focus. In fact, Bunting's case showed six primary tumors in the ileum. A detailed study of these tumors was made recently by Krompecher,[8] in an article entitled, "Basal Celled Tumors of the Cylindrical Celled Mucous Membranes, with Special Reference to Carcinoids of the Intestine."

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7. Bunting: Bull. Johns Hopkins Hosp. **15**:389, 1904.
8. Krompecher, E.: Beitr. z. path. Anat. u. z. allg. Path. **65**:79, 1919.

CASE 18.—A white man, aged 35, a patient of Dr. R. G. Sayle of Milwaukee, Wis., had an abdominal tumor and marked secondary anemia for six months. There was no obstruction. At operation, a large tumor the size of a large orange was found in the ileum. It was annular, hard, and caused dilatation rather than stenosis. There was a large mass of glands of the same size in the mesentery. Both were removed. Sections showed carcinoma which in structure was similar to the basal cell epithelioma of the skin, and not at all like an adenocarcinoma. The growth infiltrated the muscular coats, and caused extensive ulceration of the mucosa. There was recurrence four years later in the mesentery, and the patient died.

CASE 19.—A white man, aged 53, entered St. Agnes Hospital with chronic intestinal obstruction of several months' duration. At operation, by Dr. Bloodgood, a stricture with indurated wall was found in jejunum. Resection and anastomosis were done. Sections showed adenocarcinoma with metastasis to the mesenteric glands. There was a recurrence in the scar five months later, and the patient died in spite of radium treatment.

CASE 20.—A negro, aged 68, who had chronic intestinal obstruction, was given a clinical and roentgen-ray diagnosis of carcinoma of the colon. At operation, by Dr. E. F. Holman, at Johns Hopkins Hospital, a large hard mass was found in the lower portion of the ileum, causing stenosis. Resection was done. Sections showed infiltrating adenocarcinoma. The patient died a few days after the operation.

PAPILLARY ADENOMA OF THE SMALL INTESTINE

In three cases diagnosed as adenoma of the small intestine, all the tumors were pedunculated and each was causing intussusception. The patients were all under 30 years of age. Two had multiple tumors. There was no stenosis, and the obstructive symptoms were due to the intussusception. The microscopic picture was that of a mass of intestinal glands cut in various angles, and showing no evidence whatever of carcinoma. The gross tumors felt soft, and the papillomatous appearance rendered their diagnosis easy. These tumors should properly be regarded as benign tumors, although some pathologists claim that they often undergo cancerous degeneration.

CASE 21.—A white man, aged 24, a patient of Dr. S. H. Watts, at Johns Hopkins Hospital, had incomplete intestinal obstruction. The first operation was reduction of the ileocecal intussusception. The second operation, one week later, was for recurrence of the intussusception; 17 inches (42.5 cm.) of ileum were resected. This contained four papillomatous tumors, all pedunculated, the largest of which was 3 by 4 cm. Sections showed papillary adenoma. A third operation was performed, two months later, when resection of the cecum was done for a fifth pedunculated tumor of the same gross and microscopic nature. There was immediate recovery, but the patient has not been heard from since.

CASE 22.—A white girl, aged 11, had chronic intestinal obstruction and intussusception. At operation, an intussusception high in the small intestine (jejunum) was found and reduced. Four pedunculated tumors arising from the mucosa were removed through an enterostomy opening. Sections showed papillary adenoma. Recovery was immediate, but the patient died later from other causes.

CASE 23.—A negro, aged 30, a patient of Dr. G. J. Winthrop, of Mobile, Ala., had acute intestinal obstruction. At operation, an intussusception in the ileum which was caused by a pedunculated tumor, papillomatous in character, was found. Resection was done. Sections showed papillary adenoma. The patient was living and well six years after the operation.

MYXOFIBROMA OF THE SMALL INTESTINE

CASE 24.—A white woman, aged 67, who had suffered from chronic intestinal obstruction with nausea and vomiting for ten months, had a tumor in the right lower quadrant of the abdomen for seven months. She felt severe pain and lost weight. The clinical and roentgen-ray diagnosis was carcinoma of the colon. At operation, at St. Agnes Hospital, by Dr. Stewart, an ileocecal intussusception was found, and resection of the ileum and the cecum were done. When the specimen of the intestine was opened, a fibrous tumor, in part hemorrhagic, pedunculated, 6 cm. long and 3 cm. in diameter, was found attached to the wall of the ileum. Sections showed a tumor composed of fibrous tissue, the cells of which were actively proliferating. Other portions of the tumor showed myxomatous areas. It was very vascular in places. A few intestinal glands were seen, but there was no evidence of carcinoma. The patient died several days after operation.

CONCLUSIONS

1. The lymphoblastoma is the commonest tumor in the small intestine, in this series three times as common as either the carcinoma or adenoma. Spindle cell sarcoma of the small intestine has never been observed in the Surgical Pathological Laboratory of Johns Hopkins Hospital.

2. Males are more susceptible to all tumors of the small intestine than females, the proportion being more than two to one.

3. The adenoma occurs in persons under 30, carcinoma in those over 35. The lymphoblastoma may occur at any age, but a large proportion, over 40 per cent., are in children under 10 years of age.

4. Carcinoma infiltrates early and gives rise to annular growths; adenoma does not infiltrate, and is usually polypoid; the lymphoblastoma may be either annular, polypoid or fungoid, but the form of growth in the latter bears no relation to the tumor's malignancy.

5. Carcinoma is usually single, adenoma often multiple. The lymphoblastoma is occasionally multiple, particularly when the tumors are growing in polypoid form.

6. Intussusception frequently accompanies tumors which are polypoid or fungoid, being present with almost all in this series, either benign or malignant. Only a small percentage of the annular tumors are thus complicated.

7. Stenosis is the rule in all annular tumors.

8. The adenocarcinoma is always malignant, the adenoma always benign. The lymphoblastoma may be either benign or malignant, and there is no possible way to tell whether a tumor of this nature will recur or not, even from careful study of microscopical sections.

CYSTS OF THE PANCREAS*

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I have endeavored to compile all cases of cysts of the pancreas from the members of the Chicago Surgical Society for a careful study and report. The classification (modified from Oser [1]) is as follows:

I. Retention Cysts.
  A. Chronic indurative pancreatitis.
  B. Compression of duct from without.
  C. Obstruction of duct from within, as by calculi, parasites or catarrhal inflammation.

II. Cystic Neoplasms (proliferation cysts).
  A. Congenital.
    1. Dermoid.
    2. Congenital cystic disease.
    3. Teratoma.
    4. Fetal adenoma.
    5. Mixed tumor.
  B. Acquired.
    1. Cystadenoma.
    2. Epithelioma cystica.

III. Pseudocysts.—cysts resulting from hemorrhage, degeneration or necrosis.
  A. Intrapancreatic.
    1. Degenerating tumors, sarcoma, carcinoma, etc
    2. Trauma.
    3. Vascular disease.
    4. Acute pancreatitis.
  B. Extrapancreatic.
    1. Caused by same factors as the intrapancreatic pseudocysts.

IV. Parasitic Cysts.
  A. Echinococcus.

Pancreatic cysts arising from dilatation of the ducts or proliferation of epithelium are often classified as true cysts. Those dependent on traumatic or degenerative changes within the gland are called pseudocysts. They may sometimes be differentiated by the presence of an epithelial lining of the cyst wall in the former while it is only dense connective tissue in the latter. This epithelial lining may not always persist in the so-called true cysts and it is, therefore, often impossible to differentiate them from the pseudocysts.

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*Read before the Chicago Surgical Society, May 2, 1924.

1. Oser: Diseases of the Pancreas, Nothnagel's Encyclopedia of Practical Medicine, Philadelphia, W. B. Saunders Company, 1905.

The most frequent cause of retention cysts is believed to be chronic pancreatitis, which produces a gradual stenosis of the ducts. This may occur at one portion or involve the whole gland, with single or multiple cyst formation. Senn [2] has shown experimentally that sudden complete obstruction of the pancreatic duct will not produce a cyst although there may be some dilatation of the ducts beyond. He showed that, experimentally, the gland might continue to secrete, and concluded that normally the secretion was absorbed. The cause of the cyst he thought must be the arrest of absorption of secretion due to changes in the secretion or to a loss of function by the blood vessels.

Thiroloix [3] produced a cyst after three months by experimentally ligating the duct and injecting a mixture of soot and carbolized liquid petrolatum. Numerous clinical cases of cysts illustrating obstruction of various types are reported. These include obstruction by pressure of a gallstone in the common bile duct (Phulpin [4]), by lymph glands, by scar tissue or by tumors in the pancreatic duct, a calculus (Tricomi [5]), parasites (Durante [6]), or inflammation of the duct itself. Judd [7] says that cysts of the pancreas are always associated with a pancreatitis.

Proliferation cysts are regarded by Oser as those resulting from tumors or as a primary cystic degeneration of the pancreas, analogous to that of the kidneys, testes or mammary gland. The occurrence of cysts, in early life, suggests that they are neoplasms arising from embryonal rests, or are due to maldevelopment of the pancreatic ducts, such as atresia, diverticulum formation, or dilatation with kinking of the duct. Some of these cysts may be analogous to congenital cystic dilatation of the common bile duct. Judd [7] and Dennis [8] report dermoid cysts. A case of Petrykowski [9] was regarded as a teratoma or fetal adenoma. Kerr [10] reports a case which microscopically resembled a teratoma. Connelly [11] reported a case of a cyst in a girl, aged 14 months, with death from obstruction of the bile ducts. Telling and Dobson [12]

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2. Senn: Surgery of the Pancreas, Am. J. M. Sc. **93**:121, 1887; ibid. **92**: 143-423, 1886.

3. Thiroloix: Quoted by Oser.

4. Phulpin: Bull. Soc. anat. de Paris, 1892, p. 9.

5. Tricomi: Gazz. d. osp. **13**:894, 1892.

6. Durante: Cong. d'ital. chir., Riforma med. **4**:359, 1893.

7. Judd, E. S.: Cysts of the Pancreas, Minnesota Med. **4**:75 (Feb.) 1921.

8. Dennis, W. A.: Dermoid Cysts of the Pancreas, S. Clin. N. A. **3**:1319 (Oct.) 1923.

9. Petrykowski: Dissertation, 1889, quoted by Oser.

10. Kerr, A. A.: Cysts and Pseudocysts of the Pancreas, Surg., Gynec. & Obst. **27**:40 (July) 1918.

11. Connelly, D. J.: Note on a Case of Pancreatic Cyst in a Child Aged 14 Months, Lancet **1**:803, 1911.

12. Telling and Dobson: Brit. J. Child. Dis. **6**:126, 1909.

report an 18 months old child who recovered following drainage of the cyst. Hulke [13] operated on a patient, 47 years old, with prolonged symptoms, in whom the tumor had existed from childhood. Death resulted from the shock. Eha [14] excised a cystic mass from a 5 months old child attached to the tail of the pancreas, composed of two distinct sacs which he believed congenital. Cystic degeneration is not infrequent in both benign and malignant tumors. Sarcoma is rare. Recently, Marogna [15] reported a case of perivascular sarcoma and one showing suprarenal tissue with a cyst. Lockwood [16] reported a case of probable primary sarcoma of the pancreas containing several small cysts with bloody contents.

Cyst formation may result following hemorrhage or necrosis not associated with tumors in the pancreas. Le Dentu [17] first suggested that a cyst might develop from a hemorrhage into the pancreatic tissue, following trauma. This type of cyst should be distinguished from a retention cyst with bloody contents.[18] A hemorrhage into the pancreas may follow an injury to the nervous system, similar to symmetric hemorrhages which occur occasionally in the suprarenals following injury to the sympathetic nervous system (Oser).

In a large percentage of the cysts of the pancreas, there is a definite history of a severe injury. The cyst may develop immediately or be noticed only after some time. Takayasu,[19] in a review of 130 cases of cysts of the pancreas, states that there was a history of trauma in thirty, and in fifteen of these, the cyst developed within three months. Kulenkampf [20] believed that trauma first produced an inflammation of the pancreas which later resulted in a retention cyst. Others believe that the hematoma may be absorbed and replaced by pancreatic secretion, and Johnson [21] believes that there may be autodigestion of the encapsulated hematoma. Most experiments in which the pancreas was crushed or injured failed to result in cyst formation. However, Lazarus [22] pro-

13. Hulke: Pancreatic Cyst Since Girlhood, Lancet **2**:1273, 1892.

14. Eha, C. E.: Case of Congenital Pancreatic Cyst, J. A. M. A. **78**:1294 (April 29) 1892.

15. Marogna: Arch. ital. di chir., April, 1923, p. 113.

16. Lockwood, C. D.: Tumors of the Pancreas, J. A. M. A. **77**:1554 (Nov. 12) 1921.

17. Le Dentu: Bull. Soc. anat. de Paris, 1865.

18. Friedrich: Quoted by Oser.

19. Takayasu: Beitrag. zur Chirurgie des Pancreas, Mitt. a. d. Grenzgeb. d. Med. u. Chir. **3**:89, 1898.

20. Kulenkampf: Fall von pancreasfistel, Berl. klin. Wchnschr., No. 7, 1882.

21. Johnson: Surgical Diagnosis, **2**:208, 1911.

22. Lazarus: Beitrag zur Pathologie und Therapie der Pankreaskrankerungen mit besonderer Beruchsichtigung der Cysten und Steine, Berlin, 1904, quoted by Opie.

duced small cysts by crushing the pancreas of a dog and, in one instance, a hematoma was the immediate result, and, at the end of forty days, a cyst was found containing 100 c.c. of watery fluid. In four of his cases, there was a severe injury followed within from one to three weeks by the development of a cyst. In one, at least, the cyst was formed by the bursa omentalis.

Degenerative changes in the blood vessels may result in spontaneous hemorrhages, followed by so-called apoplectic cysts (Oser).

The rôle of acute pancreatitis in the formation of cysts has been noted more recently. Here there may be necrosis of the lobules of the gland with or without hemorrhage. A number of such cases have been reported. As a predisposing cause, gallstones or inflammation of the gallbladder are found to be present in a majority of these cases. McPhedran [23] reported a cyst following attacks of severe biliary colic and developing one month after the onset of an acute attack of pancreatitis. Castronuovo [24] reported a patient with syphilitic hepatitis and icterus who developed a cyst ten months after medical treatment. He resected the cyst with a necrotic portion of the tail of the pancreas.

Ballin and Saltzstein [25] reported a cyst following cholecystectomy for gallstones and inflammation of the gallbladder. There were symptoms of acute inflammation of the pancreas two weeks after the operation, but they subsided in ten days with the onset of the cyst. Carslaw [26] drained a cyst, with recovery, which developed in the tail of the pancreas four weeks after the drainage of an acute distended gallbladder for gallstones and an acute pancreatitis. Archibald [27] has been able to produce acute pancreatitis in animals with normal bile by increased pressure in the ducts or increased resistance of the sphincter of Oddi; he produced it more instantly with infected bile in which there was a high salt content. Brocq and Binet [28] state that they were unable to produce a pancreatitis by injecting normal bile into the pancreatic duct except two or three hours after a meal. They were unable to produce a cyst following the injection of bile into the pancreatic duct, but they had produced one following the injection of calcium chlorid solution.

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23. McPhedran: Case of Pancreatitis Followed by Cyst of the Pancreas, Brit. M. J. **1**:1400, 1897.

24. Castronuovo, G.: Pancreatic Cyst of Luetic Origin Simulating a Tumor of the Gastrohepatic Region, Policlinico, Rome **24**:1077, 1917.

25. Ballin, M., and Saltzstein, H. C.: Cyst Following Cholecystectomy, J. A. M. A. **76**:1484 (May 28) 1921.

26. Carslaw, R. B.: Acute Pancreatitis Followed by the Development of a Pancreatic Cyst, Lancet **2**:133 (July 16) 1921.

27. Archibald, E.: Surg., Gynec. & Obst. **28**:529 (June) 1919.

28. Brocq and Binet: Pathogenie de la Pancreatite Hemorrhagique, Presse méd. **19**:219 (March 7) 1923.

Following loss of the gallbladder function, increased pressure in the bile ducts, due to vomiting or spasm of the sphincter or intestine, may occur with regurgitation up the pancreatic duct. After the sphincter has dilated, this regurgitation may occur from the duodenum. These factors may account for an occasional postoperative pancreatitis followed by a cyst.

The pseudocysts in which the wall is entirely or largely formed by structures other than the pancreas are usually in the bursa omentalis. They may result from trauma, an infective or necrotic pancreatitis. Lloyd [29] was the first to call attention to the fact that many so-called pancreatic cysts are really effusions in the bursa omentalis. He reports two cases following trauma. The onset is usually sudden in contrast to proliferation or retention cysts. Bonneau [30] believes pseudocysts are more common following hemorrhagic pancreatitis than trauma. Parasitic cysts are rare, but their presence should always be considered.

The exciting cause of the cyst in the majority of this series, given in the accompanying table, is obscure. Calculi, strictures, compression and distortion of the ducts and chronic inflammation of the pancreas may produce retention cysts. However, in the group classed as idiopathic, there was only evidence in some of chronic pancreatitis. The remaining cysts may be classified easily as traumatic, malignant, and those resulting from acute pancreatitis.

SEX

Cysts of the pancreas occur about equally in males and females. The sexes are about equally divided, in this series, except for a preponderance of males in the traumatic group. In a large series reviewed by Oser, he found that the greatest frequency occurred between the ages of 20 and 40. Takayasu states that the frequency varies between 20 and 60 years, but that cysts may occur at any age. The average age in all nineteen of these cases is 40 years. The idiopathic cases occurred from 25 to 56 years of age, the average age being 41 years, 37 for the females and 47 for the males. The average age of the four traumatic cases is 21 years, of the three malignant cases, 59 years, and of the cases following acute pancreatitis one patient was 19, and the other 67 years old.

There was no history of excessive eating or alcohol, in these cases, although it is not uncommon in the literature. It is somewhat significant that, in the ten cases of the idiopathic group, there was a history of typhoid fever in three. In one, the symptoms, of 25 years' duration,

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29. Lloyd, P.: Injury to the Pancreas, A Cause of Effusions into the Lesser Peritoneal Cavity, Brit. M. J. **2**:1051, 1892.

30. Bonneau, R.: Pseudo-Kystes Traumatiques, Presse méd. **65**:401 (Aug. 16) 1922.

A. Idiopathic Cysts

Case	Author	Age	Sex*	Symptoms	Operation	Course	Remarks
1	Bevan, A. D.	55	♂	Frequent attacks of epigastric pain, 25 years; tumor, 2 years, growing	Drainage of large cyst; removal of soaplike material from cyst	Fistula several months; closed after application of radium	Microscopic examination of cyst wall—fibrous tissue; no epithelial lining; considerable infiltration with lymphocytes
2	Cubbins	29	♂	Onset gradual, 3 weeks; tumor, 3 weeks	First operation, drainage of large cyst; second operation, drainage of abscess of pancreas	Septic fever and fistula until second operation 10 months later; death 1 month after second operation following progressive emaciation	Microscopic examination of cyst wall—fibrous tissue
3	Richter, H.	30	♀	No records; large abdominal tumor	Marsupialization	Left hospital with persistent fistula	
4	Richter, H.	35	♀	Gradual onset of upper abdominal tumor	Excision of part of sac; marsupialization of base	Persistent fistula for many months	
5	Lewis, Dean	25	♀	Intermittent epigastric pains, 7 months; tumor, 3 weeks; tenderness and rigidity, 2 months	Drainage of large cyst	Left hospital in 13 days, improved	Patient was operated on three weeks before elsewhere, but only an exploratory done
6	Bevan	45	♀	Intermittent epigastric pains, severe lately; tumor, 3 months, increasing	Drainage of large cyst; removed white mudlike substance	Rather severe postoperative hemorrhage few hours later; left hospital 7 weeks later improved; fistula present 6 months later	A secondary firm nodular mass was palpable near the cyst
7	Lewis, Dean	56	♂	Tumor, 1 year; moderate pain at times; moderate emaciation	Drainage	Discharged as cured 20 days later	
8	Coombs, S.	45	♂	Abdominal pains, vomiting and tumor	Drainage	Drained for a long time	
9	Kahlke	45	♀	Cyst operated on 13 years ago; recurrence of tumor 3 years ago; pains severe at times	Drainage	Persistent sinus, 18 months after operation; excised tissue found to be a malignant papillary adenoma; died 2 months later of hemorrhage from sinus	Roentgen-ray examination showed no signs of stones; possibly originally a cystadenoma of the pancreas
10	Beck, C.	42	♀	Gradual growth of tumor over several months; pressure symptoms with vomiting	Drainage	Drainage stopped after several months; well for many years	Pancreas transformed into a large cyst; liver negative

			B. Cysts Following Trauma			
11	Plummer and Hamilton...	24	♂	Bullet wound near pancreas; onset of tumor, nausea and vomiting 3 weeks later; symptoms severe and constant 6 weeks after injury	Drainage of cyst, 3,000 c.c. clear yellow fluid; necrosed tissue and fat necrosis removed	Uneventful recovery; entirely healed 1 month after operation	
12	Kahlke.....	21	♂	Onset gradual 3½ months ago; fall from horse 3 weeks before; colicky pains in epigastrium; loss in weight	Drainage of large cyst.....	Uneventful recovery; drainage stopped in 8 weeks	Two ferments found in cyst fluid
13	Richter, H	6	♂	Run over by a wagon 2 weeks ago; tumor in upper part of abdomen only symptom	Drainage, from 8 to 12 ounces (236 to 355 c.c.) of fluid	Drainage stopped in 5 weeks; well 15 years later	
14	Jones, H.	32	♀	Run over by automobile; tumor from 6 to 7 days later; symptoms, vomiting and pressure	Exploratory, 12 hours after injury; drainage of cyst 11 days later; bloody; 1,500 c.c. removed	Drainage stopped 5½ months later; recovery	Trypsin, rennin, steapsin and amylopsin in cyst in nonactive form; activated by adding duodenal contents of dog
			C. Cysts with Malignant Tumors			
15	Phemister.	64	♂	Pains in abdomen and back, 6 months; tumor enlarging, 3 months	2,000 c.c. of clear fluid aspirated at operation; removed nodules in mesentery; a second hard mass in head of pancreas	Cyst gradually refilled; death 3 months later; no necropsy	Microscopic examination of nodule in mesentery; adenocarcinoma; pancreatic ferments in fluid
16	Graham, D. W.	68	♂	Onset gradual 2½ months; progressive jaundice; fulness in epigastrium; loss of weight	Small cyst drained; clear fluid; a hard carcinomatous mass in head of pancreas; gallbladder also drained	Died the day of operation; no necropsy	
17	David, V. C.	45	♂	Rapidly growing tumor filling abdomen; loss of weight; very slight other symptoms	Aspiration of bloody fluid, 4,000 c.c.; hemorrhagic nodular thick wall of cyst; abdomen closed without drainage	Death few days later, with symptoms of hemorrhage into cyst	Necropsy showed no general or local metastases, but a degenerating cystic tumor; microscopic examination—degenerated tissue and smooth muscle
			D. Cysts Following Acute Pancreatitis			
18	Percy and Nadeau.....	19	♀	Sudden onset, shock, vomiting, pain, rigidity, temperature 104 F.	Drainage of pancreas, cyst, lesser omentum, gallbladder; removed gallstones	Recovery; drainage stopped in 3 weeks	Gallstones in gallbladder and common duct; gallbladder acutely distended; pancreas contained a cyst, grapefruit size, with bloody, flaky contents; discharge sterile
19	Smith, Joseph.....	67	♂	Operation for an upper abdominal abscess some years before; well until sudden acute onset with severe abdominal symptoms	Not operated on.....	Died 6 days after acute onset	Necropsy; pancreas enlarged; fist size cyst filled with pus and blood; fat necrosis; old adhesions; liver and gallbladder negative

* In this column, ♂ indicates male, ♀ female.

developed two years after typhoid, but in the others the symptoms developed thirty and forty years later. There was no notation of excessive obesity. In six cases of the idiopathic group, there was loss of weight with some emaciation, with the development of the cyst. One patient (Case 1) lost 50 pounds (22.7 kg.). In two cases, there was no loss of weight. In the remaining two, there was no record. In the traumatic group, the only patient (Case 12) that went for longer than three or four weeks lost 20 pounds (9 kg.) in weight. In other cases, there was no record. In the malignant group, there was loss of weight noted in all. There had been no previous loss of weight in the cysts that were associated with the acute pancreatitis.

The onset of the cyst following pregnancy occurred in two cases in the idiopathic group; in Case 5, three months after childbirth, and in Case 6, one month after a cesarean section. There are a number of reported cases which were discovered immediately,[31] or developed soon after childbirth.[32] Russ [33] reports a pseudocyst apparently due to hemorrhagic necrosis of the pancreas occurring during a sepsis after childbirth. In regard to acute pancreatitis, a number followed shortly after pregnancy and were not associate with suppuration.

Gallstones and gallbladder disease are frequently associated with cysts of the pancreas. Ipsen [34] reports disease of the gallbladder in 40 per cent. of the Rovsing series of cysts. Judd reports inflammation in two, and stones in fifteen, of forty-one cases of cysts. In only one case (Case 18) were gallstones found, in this series, but the acutely inflamed gallbladder containing stones, the stones in the common duct, and an acute pancreatitis associated with the onset of this cyst are suggestive of the cause and the chronological course of events.

The traumatic group gives a history of direct injury followed by the cystic tumor. This occurred in three cases within from one to three weeks. The injury was due to a machine gun bullet wound in one. In Cases 11 and 12, the tumor was small at first and increased gradually.

In the three malignant cases, the tumor developed gradually within from two to three months.

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31. Primrose, A.: Pancreatic Cyst and Pseudocysts, Surg., Gynec. & Obst. **34**:431 (April) 1922.

32. Mayo, W. J.: Pancreatic Cyst, M. Rec. **45**:168, 1894. McCann, F. J.: A Large Pancreatic Cyst Simulating an Ovarian Tumor, Proc. Roy. Soc. Med., 1913.

33. Russ, W. B.: Pseudocyst of Pancreas Apparently Due to Hemorrhagic Necrosis Occurring During the Course of General Sepsis, J. A. M. A. **77**:621 (Aug. 20) 1921.

34. Ipsen, quoted by Boumann (Footnote 44, second reference).

PATHOLOGY

The size of the cyst varies. It is usually spherical and consists of one large sac, but it may be multiple in either the retention or congenital type. If obstruction occurs near the outlet of the main duct, there may be a cystlike dilatation of the duct, or a beaded rosarylike dilatation of the whole duct, which Virchow [35] describes as ranula pancreatica. If numerous smaller ducts are constricted by a general inflammatory process, multiple small cysts filled with mucoid secretion are formed, which Krebs describes as acne pancreatica. The shape in cases in which the cyst is formed by the bursa omentalis may be of diagnostic value. In none of this series was it described as anything but spherical, although in one case it was found to be in the bursa (Jones). The size was about that of a grapefruit in Cases 18 and 19, and much larger in all the others, except Case 16. In Case 1, it contained 2 gallons (7,569 c.c.); in Case 4, 1 gallon (3,784 c.c.); in Case 11, 3,000 c.c.; in Case 14, 1,500 c.c., and in Case 17, 4,000 c.c.

The location of the cyst was described as arising from the middle of the pancreas in Case 4, and from the tail in Case 15. The cyst was present in the head in Case 16. In general, the tail seems to be the most frequent location for the cyst. Oser found the location, in forty-four cases out of 134 reviewed, to be as follows: fifteen in the tail; eleven in the head; four in the middle portion, and fourteen involving the entire pancreas.

The head was large in Cases 2, 6 and 15. The cyst presented at operation as follows: (1) in the idiopathic group, between the stomach and transverse colon in three cases, and above the stomach in two cases; (2) in the traumatic group, between the stomach and colon in three cases; (3) in the malignant group, between the stomach and colon in one case, and (4) in the pancreatitis cases, there was no record. There was extensive fat necrosis in the pancreatitis cases. There was fluid in the general peritoneal cavity in only Case 18. The peritoneum of Case 19 was hemorrhagic.

The cyst contents were described as brownish fluid with several masses of gray soft material (Case 1) and as a milky fluid, containing a white, mudlike material (Case 2), in the idiopathic group. They were described as a clear yellow fluid in Case 11; as a clear fluid in Cases 15 and 16; as bloody in Case 17, and as blood and pus in one (Case 19).

The digestive action of the contents, in Case 12, split fats and digested starches. In Case 14, the ferments trypsin, rennin, amylopsin and steapsin were demonstrated by Dr. Becht of Northwestern University Medical School. They were nonactive as they came

35. Virchow: Ueber Rannula Pancreatica, Berl. klin. Wchnschr., 1887, p. 248.

from the fistula in the latter, but were activated by addition of a dog's duodenal contents. Johnson states that ascites fluid may digest cooked starches. Digestive action of the cyst contents on the skin was absent in all except Cases 12 and 18. In Case 12, it was described as slight.

The bacteriology was reported in only three cases. It was sterile in Cases 2, 13 and 18. In Case 19, gross pus was present in the contents.

The wall was described as fibrous and about one-fourth (0.6 cm.) inch thick in Case 1, and as thick and nodular degenerating tumor tissue in Case 17. A microscopic report, in Case 1, stated that it consisted of fibrous tissue with round cell infiltration; in Case 2, of only fibrous tissue; in Case 17, the grossly malignant tissue was so badly degenerated that a microscopic diagnosis could not be made. However, one section showed smooth muscle fibers without epithelial cells. A microscopic report from a metastatic nodule, in Case 15, showed it to be adenocarcinoma. While Case 9 is included in the idiopathic group on account of the long intervening years free from symptoms, sections taken from a papillomatous mass projecting from the fistula eighteen months after the last operation showed it to be a malignant papillo-adenoma. This is similar to a case of Speese,[36] in which operation had been done ten years before for a cyst; the patient remained well for seven years, and then developed this slow growing malignant cystic adenoma. Fitz [37] states that multilocular cysts resembling those of the ovary are reported. They are benign, and the walls are lined with cylindrical or polygonal epithelium; others have papillary growths present. They may resemble cystadenoma of the breast. As the cysts become larger, the epithelial lining may disappear, and with it gone there may no longer remain any clue to the origin of the cyst.

SYMPTOMS

In discussing the symptoms, it is evident that one should differentiate between the types of cysts. The symptoms of the idiopathic group are of considerable interest. There was a definite fluctuation in the size of the tumor in two cases. In one (Case 6), the variation bore no relation to meals or to pains. A history of previous attacks of pain over a long period was present in seven of the ten cases. In one, at least, there were no symptoms except the tumor, while, in the other two, the records made no mention of any other complaints. The longest duration of symptoms was twenty-five years with intermittent, severe attacks, many lasting from three to four weeks, in which the tumor itself was only of two years' duration. Most cases were of several years' duration, but

36. Speese: Cystadenoma of Pancreas with Extension to Abdominal Wall Ten Years After Drainage of Cyst, Ann. Surg. **61**:759, 1915.

37. Fitz: Multilocular Cystoma of Pancreas, Tr. A. Am. Phys. **15**:255, 1900.

a few came to operation after a few weeks or months of symptoms. Pain was one of the most constant symptoms. It was stated definitely to be absent in only one case (Case 10). It was usually intermittent in character and referred to the epigastrium. However, in two cases (Cases 7 and 9) in which the tumor was in the left upper quadrant, the pain was in that region. In one case, attacks came on about three hours after eating. These attacks were relieved by eating, taking bismuth and chalk powders, and usually by catharsis. In other cases, the severe, irregular attacks of pain would last about one-half hour, and occasionally require morphin. There would remain a persistent soreness. Vomiting was recorded as present in four, and absent in three cases. Takayasu found colicky pains in the stomach were complained of sixty-four times, and that they occurred after meals twenty-eight times, in a review of 104 cases of cysts. He attributes the symptoms to pressure.

Emaciation was noted in four, and was absent in two cases. In Case 1, while the symptoms were of long duration, the patient lost 50 pounds (22.7 kg.) only recently; another (Patient 6) lost 30 pounds (13.6 kg.).

The location of the tumor, by palpation, in the groups was found to be: in the idiopathic group, in the epigastrium five times, and in the left upper quadrant, three times; in the traumatic group, in the left upper quadrant, three times; in the malignant group, in the epigastrium twice, and in the left upper quadrant once; in the acute pancreatitis group, the tumor was not palpable on account of the tympanitis.

The onset and growth of the tumor was usually gradual, without any acute symptoms. The course was usually afebrile before operation. An exception was perhaps Case 1, with one febrile attack about the time the tumor appeared, and Case 6 with a daily rise of temperature of one-half degree, after the tumor had developed. Rigidity and tenderness in the region over the tumor were mentioned as present twice and absent three times. In one case (Case 10), rigidity was very marked in the epigastrium, but there was no tenderness.

In the traumatic group, the cysts developed shortly after injury, and increased rapidly in size. Nausea and vomiting occurred, except in Case 13, and increased with the size of the tumor. There was not always tenderness or rigidity. Fever and chills, from 99 to 102 degrees, were noted in Cases 12 and 14, shortly after injury. The pulse was 46 in Case 12, and 140 in Case 14. There was constipation in Case 12. In the malignant group, the onset was from two to six months' duration. There was almost a lack of any symptom except the progressively growing tumor with emaciation; there was no vomiting and no fever. A progressive jaundice developed in Case 16, the only instance in the series. In the acute pancreatitis cases, the tumor was not diagnosed, but this was largely due to the distention. Here the onset was sudden, due to

the acute pancreatitis. The temperature was subnormal in Case 18, and 101 in Case 19, with suppuration. The pulse varied in Case 18 from 88 to 140, and in Case 19 from 80 to 120.

LABORATORY FINDINGS

In the idiopathic group, the blood showed no changes except slight secondary anemia associated with loss of weight. There was no sugar in the urine. The stools were negative as far as noted. The stomach tests were made in only two: Case 1 showed free hydrochloric acid 45, and total acid 56; Case 2 had a negative stomach analysis and roentgen-ray examination.

In the traumatic group, in Case 11, the white blood cells were 11,900; polymorphonuclears, 63 per cent., and hemoglobin, 85 per cent. In Case 14, in which the tumor developed suddenly, the leukocytes were 40,000, eleven days after injury. The urine contained albumin and red cells.

In the malignant group, there was anemia in Case 15; in Case 16, the urine contained bile and albumin; leukocytes totaled 17,650, and hemoglobin was 51 per cent.; the stools were mushy and light brown.

In the pancreatitis cases, the urine in Case 18 contained a large amount of albumin with pus and a few casts. The leukocytes were 33,000, and the hemoglobin, 90 per cent. In Case 19, there was a marked amount of sugar with albumin and casts in the urine.

DIAGNOSIS

The diagnosis before operation, in the idiopathic group, was made correctly in three cases, not stated, in four cases, and incorrectly diagnosed as a retroperitoneal sarcoma, floating kidney and merely tumor, in other cases. In the traumatic group, it was correctly diagnosed, in three cases, but, in Case 14, it was thought to be an abscess in the lesser sac. The malignant cases were diagnosed merely as cyst of the pancreas, in two cases. In the pancreatitis group, the cyst was not discovered until operation. In the whole series, we see, by the records, that a cyst of the pancreas was correctly diagnosed in only seven of the nineteen cases. In several cases in the literature, it has been diagnosed an ovarian cyst. Lloyd calls attention to the shape of the tumor following the outline of the bursa omentalis as an aid to the diagnosis of pseudocysts. It should be stated that the fluoroscope and roentgenograms may be of considerable value in the differential diagnosis.

PROGNOSIS

The tendency is for pancreatic cysts to increase in size and in symptoms. Johnson states that there are a number of cases in which there

was a traumatic or spontaneous rupture of the cyst with fatal results. Occasionally, they may rupture spontaneously into the intestinal tract, as in Payr's [38] case in which the cyst ruptured and recurred repeatedly. Six of these nineteen patients died as a result of the cyst or associated complications, a mortality of 31 per cent. Patient 2 died as a result of secondary infection in the region of the pancreas; Patient 9 developed a carcinoma along the fistula, and death resulted from an acute hemorrhage. In Cases 15, 16 and 17, the cysts were probably the result of a malignant tumor and all the patients died. In Case 19, the cyst was a complication of a suppurative pancreatitis. There were two operative deaths, an operative mortality of 10.5 per cent. They were both in the malignant group: Patient 16 died the day of operation, but she was jaundiced and in poor condition; Patient 17 died the second day, probably as the result of an acute anemia, due to refilling of the evacuated cyst with blood. The persistent sinus apparently was the cause of infection and sepsis of the pancreas, in Case 2, and, in Case 9, it may have been a factor in the malignant transformation. The sinus was reported as healed in eight of the thirteen patients that lived. In the other five, the sinus was still present when the patient left the hospital, or on the latest observation. It persisted in the idiopathic group, usually several months; in only one case did it close quickly (Case 9), in twenty days. In the traumatic group and in the pancreatitis case, the sinus closed very promptly. Bonneau states that, following drainage of a traumatic cyst, the antidiabetic diet of Wohlgemuth [39] usually results in a rapid lessening of secretion, while in the nontraumatic cases, the results are less satisfactory.

In Case 1, the sinus closed after several months, following the application of radium. Hamilton [40] also reports a case in which the fistula closed shortly after the application of radium. Opie [41] advises against the injection of fluids into the sinus as dangerous. Patient 10 was reported well many years later, and Patient 13, fifteen years later.

Diabetes did not develop after operation as far as known. Sugar was present, on entrance, in the urine in Case 19, an acute fatal pancreatitis, but there was no history of diabetes. Diabetes occurred in nine of 134 cases, reviewed by Oser. There was a recurrence of the cyst, in Case 9, as a malignancy eight years after apparent cure from drainage. Recur-

38. Payr, E.: Pankreas Cyste, seltene Topographie, Operation und Heilung, Wien. klin. Wchnschr. **11**:629, 1898.

39. Wohlgemuth: Berl. klin. Wchnschr. **44**:47, 1907.

40. Hamilton: Prolonged and Profuse Postoperative Drainage of Pancreatic Cyst and Use of Radium, Surg., Gynec. & Obst. **35**:655 (Nov.) 1922.

41. Opie: Diseases of the Pancreas, 1910.

rence following drainage is occasionally reported. McWilliams [42] reports a recurrence one year later. This patient was operated on again; a fistula followed for seven years, and then spontaneous healing occurred.

TREATMENT

In the acquired cysts, preventive treatment may be of value in removing causes of chronic or acute pancreatitis, such as neighborhood or focal infections and gallstones. All cases in the idiopathic group were drained; Case 11 had both anterior and posterior drainage. Marsupialization was the method used in five of these. In the malignant group, Patient 15 was aspirated; the other two were drained. In the pancreatitis cases, in Case 18, the cyst and gallbladder were drained with the removal of stones. Patient 19 was not operated on because of poor condition. Eight of the members of the Chicago Surgical Society have given their opinion as to when they would operate on a pancreatic cyst. Six state that they would operate as soon as diagnosed. Two state that they would depend on the symptoms and, of course, the general condition before operating.

Successful operative excision was first done by Bozeman.[43] Since then a few cysts favorably located, usually in the tail of the pancreas, have been excised with recovery.[44] Judd states that five of forty-one cysts were excised, while in three others he enucleated the lining.

Gussenbauer [45] instituted drainage successfully. Oser, in reviewing 134 cases, found 101 operations with eighty-one recoveries. The incision and drainage operation, in one stage, was done fifty-eight times with seven deaths, but four were independent of the operation. Puncture was done in seven with five deaths. Extirpation was done in eleven with two deaths. Partial extirpation or drainage at a second stage was done in a few cases.

Apparently, complete excision should be attempted only where the cyst is located in the tail or has a pedicle, because of the dangers of hemorrhage and injury to the ducts. Drainage of the cyst, in selected cases with partial excision, has resulted in a high percentage of cures with a low mortality, and may be wisely chosen in the majority of cases.

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42. McWilliams, C. A.: True Pancreatic Cyst, S. Clin. N. A. **3**:439 (April) 1923.

43. Bozeman: M. Rec. **21**:46, 1882.

44. Willis and Budd: Surg., Gynec. & Obst. **20**:688, 1915. Boumann, H. A. H.: Minnesota Med. **5**:697 (Dec.) 1922.

45. Gussenbauer, C.: Zur Operation Behandlung der Pankreas-cysten. Arch. f. klin. Chir. **29**:355. 1883.

TWENTY-SEVENTH REPORT OF PROGRESS IN ORTHOPEDIC SURGERY

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(Continued from Page 488)

OSTEOCHONDRITIS DISSECANS

Krida,[41] reporting three cases of osteochondral fracture of the knee joint, states that the condition corresponds in some particulars to Koenig's osteochondritis dissecans. It occurs usually in young adults and is produced by a direct blow on the knee. The trauma produces an osteochondral fracture of a section of the articular portion of the internal condyle without primary displacement of the detached fragment. There are three phases: (1) when the detached fragment is still loosely attached by connective or fibrous tissue; (2) when it is detached but has not been extruded from its crater, and (3) when it is a loose body in the joint. The first phase is hard to demonstrate by roentgen-ray examination. The second is more distinct. The author feels that since diagnosis is so difficult, arthrotomy is justified to determine the exact condition, and he advises the used of the curved incision running from the patellar tubercle upward to the inner side of the patella.

Synovectomy in the Knee Joint.—Steindler,[42] reporting twenty operations of synovectomy in fourteen patients, draws attention to the fact that beyond the primary purpose of removing diseased synovial tissue which forms an important local focus of infection, much benefit is obtained by the better alinement and improved weight-bearing mechanics. In 60 per cent. of the cases the painful symptoms were relieved and better function was obtained, even though the range of motion was not increased. He attributes this failure to restore motion to the formation of scar tissue and to the activity of the disease. Obtaining an accurate diagnosis he considers to be not the least of the advantages of operation.

Arthroplasty of the Knee.—Ceballos,[43] reporting his results in arthroplasty of the knee, states that excellent results were obtained in

41. Krida, A.: Surg., Gynec. & Obst. **39**:791 (Dec.) 1924.
42. Steindler, Arthur: J. A. M. A. **84**:16 (Jan. 3) 1925.
43. Ceballos, in Mouchet, Albert: Bull. et. mém. Soc. Nat. de Chir. **51**:2 (Jan. 17) 1925.

68 per cent. of the cases. He has employed a median patellar splitting incision and remodeled the bone to as near the normal as possible, and then interposed a free fascial transplant. Following operation he immobilizes with extension for about fifteen days, and then encourages gentle motion in a systematic way for from five to six months. He believes that cases with ankylosis in extension are more favorable than those with ankylosis in flexion. He agrees with most other writers that recent arthritis, tuberculosis, debilitation and neurosis are contraindications to operation. He believes that slight abnormal lateral mobility is necessary for success and is not troublesome if the muscles are in good tone. On the other hand, the removal of too much bone may result in too great instability, which is bothersome.

Astragalectomy in Paralytic Deformities of the Foot.—MacAusland and MacAusland,[44] reporting their experience with the Whitman operation of astragalectomy, express their satisfaction with the procedure, which they consider the operation of choice in most of the paralytic deformities of the foot. They state that the object of the operation is not arthrodesis, but stabilization of the ankle joint. While best suited to calcaneus deformities, the authors report good results in equinus deformity, after previous stretching in plaster. In calcaneovarus the deformity of the forefoot must be overcorrected in plaster for months if a satisfactory result is to be obtained.

Critical Consideration of Astragalectomy for Paralytic Feet.—Satta [45] discusses the various indications for astragalectomy as advanced by Whitman and others, and concludes as follows: In paralytic conditions of the lower extremities there is not a single rational indication for astragalectomy furnished by a sound conception of reparative surgery, even for the correction, in an anatomic and functional sense, of the lesions and residual deformities. It is an exceptional operation and today deserves to be abandoned, to give place to active or passive methods of plastic correction of the soft parts and of the skeleton.

Two Hundred Cases of Paralytic Foot Stabilization After the Method of Hoke.—Miller [46] believes that it has been definitely established that an understanding application of Hoke's operation, together with the proper tendon transplantation and skeletal alinement, will meet all the surgical needs of the paralytic foot more nearly and more lastingly and with more natural preservation of the function and appearance of the foot than does any procedure yet devised. In the clinic of the North Carolina Orthopedic Hospital for the last three years no other type of

44. MacAusland, W. R., and MacAusland, A. R.: Ann. Surg. **80**:861 (Dec.) 1924.

45. Satta, F.: Chir. d. org. di movimento **9**:37 (Dec.) 1924.

46. Miller, O. L.: J. Bone & Joint Surg. **7**:85 (Jan.) 1925.

operation has been used for stabilizing paralytic feet, and Miller's report contains a review of the different surgical efforts. In the first place he points out that in this group of cases no braces were applied for foot conditions. He believes that the success of this operation lies in the exactness with which the head of the astragalus is fitted to its new function for maintaining the corrected position in the foot. He believes that in the varus type of foot the hypertrophy of the os calcis and cuboid necessitates the removal of a wedge of bone at their junction. He states that at the time of operation it may be possible to place the head of the astragalus in perfect position and hold it there. About five or six weeks after the operation the foot is remanipulated, but at this time there has taken place a moderate union throughout the area of fusion, but not enough to prevent an improved alinement of the head of the astragalus provided this is necessary. He recommends the operation for four types of foot deformity: varus, flatfoot, calcaneus and flail foot. In 25 per cent. of the cases of varus deformity osteotomy was necessary to correct torsion of the tibia; in other types it is rarely needed.

[ED. NOTE.—We feel that this enthusiastic paper on the use of Hoke's operation for stabilization of paralytic feet should not pass without a word of warning. We remember similar papers that have enthusiastically proclaimed the satisfactory results that followed the universal use of Whitman's operation, astragalectomy. It seems to us that a word of warning is in place because these operations are usually done on growing bones in the feet of children, and experience has taught that with growth and development, unless great care is taken to prevent the reestablishment of deformity, it is apt to reappear, no matter what type of stabilization has been done.]

End-Results of Operation for Claw Foot.—Smith and von Lackum [47] report an end-result study of 186 operations for claw foot in 125 patients. The operative procedure was the one devised by Hibbs and consisted in the transplantation of the tendons of the extensor longus digitorum and the extensor longus hallucis into the cuneiform bones. The original condition for which the procedure was carried out was claw foot deformity with hammer toes, impaired transverse arch, callus formation, and more or less severe cavus. In addition there were in this series a number of cases with various other types of foot deformity, which included hyperextension of the toes, but which were not in other respects typical claw foot, the field of usefulness of the operation thus being extended beyond what was originally intended. Other operative procedures were carried out when indicated, either preliminary to or in conjunction with the tendon transplant. The pur-

47. Smith, A. De F., and von Lackum, H. L.: J. A. M. A. **84**:499 (Feb. 14) 1925.

pose of the operation is to remove the deforming action of the long extensors of the toes and to enhance their power as dorsiflexors of the foot. They conclude:

1. The results of operation for transplant of the long toe extensors in cases of claw foot are satisfactory in properly selected cases.

2. The cavus deformity first must be thoroughly corrected, this usually necessitating resection of the mediotarsal joint without extensive division of the plantar structures.

3. Any equinus must be corrected before or at the time of operation.

4. If any lateral instability is present a subastragaloid arthrodesis should be performed prior to the transplant.

5. No other procedure involving trauma to the foot should be combined with the transplant operation.

6. The causes of bad results were failure to splint the toes long enough, with resulting tendency of the toes to curl under; incomplete correction of cavus deformity; drop foot, because of weakness of the anterior muscle group including the transplanted muscles, and lateral instability.

7. The negative effect of transplantation on the toes may be good even though the transplanted muscles are too weak to have much positive effect in producing dorsiflexion of the foot.

Indirect Neurotization of Paralyzed Muscles. — Deutschlaender [48] has combined Erlacher's method of neurotization of paralyzed muscles into healthy muscles with transplantation of the tendons of the latter. He cites as an example a paralysis of the anterior tibial with good preservation of the extensors of the toes. The tendon of the extensor hallucis was transferred after the method of Biesalski by drawing it through the tendon sheath of the anterior tibial and fastening it on the periosteum of the first metatarsal bone. The upper end of the anterior tibial was cut off near its origin and the distal segment, tightly drawn, was implanted in the freshened area of the extensor hallucis. He has done this or a similar operation in nine instances, and he believes that function of the transplanted muscle is better than in corresponding cases in which neurotization had not been attempted.

Segmental Osteotomy for Bow-Legs.—Pieri [49] reports a case of operative correction of bow-legs by the method of Springer. Springer exposes the tibia, opens the periosteum, and removes a section of the tibia from 3 to 6 cm. long. He cuts this into disks about 1 cm. thick, and after replacing them in the periosteal tube closes the periosteum. He then does an osteoclasis of the fibula, remodels the leg, and applies

48. Deutschlaender: Ztschr. f. orthop. Chir. **46**:103.

49. Pieri, Gino: Chir. d. org. di movimento **9**:97 (Dec.) 1924.

a plaster cast. The result in Pieri's case was excellent. The advantages claimed are: 1. Correction of the curves in both anteroposterior and lateral planes at one sitting. 2. A more or less straight correction, rather than by making angles. 3. Lengthening of the legs.

[ED. NOTE.—This procedure would seem very severe for any other than exceptional cases.]

FRACTURES

Kümmell's Disease.—Zamboni,[50] reporting two cases of post-traumatic spondylitis of Kümmell, states as his conclusions that the manifestations are due to the refracture of the callus of a fracture of the body of a vertebra, which may be complete or incomplete. The refracture is due to a mechanical strain caused by abnormal function of the muscles, tendons and ligaments acting on insufficient callus formed by bone that is atrophic from vascular and nerve changes. In both of Zamboni's cases there was originally a definite fracture with few immediate symptoms and only a short period of disability, followed by a period of well-being. Subsequently the disability recurred. Influenced by the rapid recovery in one of his cases following an Albee bone graft, Zamboni advocates this form of treatment.

Avulsion of Anterior Superior Iliac Spine.—Ord [51] reports two cases of avulsion of the anterior superior iliac spine in 17 year old boys, which were brought about by kicking a football. Both cases were treated by open operation with suture of the avulsed spine with chromic catgut. Firm union occurred rapidly, and both were playing football again in three weeks. He explains that the probable etiology is the overaction of the sartorius when the thigh is semiflexed, adducted and internally rotated.

Fracture of the Hip.—Anschutz,[52] writing on subcapital fractures of the neck of the femur, points out the extreme importance of an adequate blood supply to the proximal fragment. Even if sufficient blood is carried to the head by vessels running in the ligamentum teres, the central fragment is unable to produce any amount of callus. Also the nutrition to the upper end of the distal fragment is unfavorable, although a certain amount of nutrition may be provided by the capsular vessels. Union occurs only by internal callus formation. Necrosis and absorption are common results and pseudo-arthrosis may result even when there is apparent impaction. Anschutz has used the Whitman method of treatment and states that with it he has obtained good results in two thirds of the early cases and satisfactory results in four fifths

50. Zamboni, G.: Chir. d. org. di movimento **9**:105 (Dec.) 1924.
51. Ord, A. G.: Lancet **2**:1230 (Dec. 18) 1924.
52. Anschutz, W.: München. med. Wchnschr. **72**:454 (March 13) 1925.

of all cases. In early cases the results are better than with the operative treatment, either excision or transplantation of the trochanter. In old cases with severe symptoms he favors inserting the trochanter into the acetabulum, with the intention of obtaining a stiff but painless weight-bearing leg.

Koenig [53] recommends operative treatment in early cases of subcapital fracture of the femoral neck when there is no hope of bony union. He employs the Langenbeck incision, resecting the trochanter, and turning back a good sized flap of muscle, periosteum and bone. The head of the femur is excised with a portion of the neck and trochanter; the top of the shaft is rounded off and inserted in the acetabulum. The trochanter with its attached muscles is then fixed to the shaft at a lower level than the original insertion, thus maintaining the muscle action. Early weight-bearing is permitted in a plaster spica. The result is a stiff but good weight bearing hip.

[Ed. Note.—The procedure advocated by Koenig appears to be very similar to the one devised by Whitman and known as the reconstruction operation. Not only does it needlessly sacrifice length, but it only achieves an ankylosis, whereas the Whitman procedure obtains stability with an excellent range of motion.]

Fractures of the Shaft of the Femur.—Conwell [54] reports a careful and detailed study of 110 cases of fracture of the shaft of the femur. Severe contusion of the soft structures was noted in 50 per cent. of the cases. Nine of the fractures in the lower third involved the knee joint. Eighty per cent. of the cases were treated by direct skeletal traction (calipers) in conjunction with the Thomas splint, hinged knee support and overhead suspension. Open reduction was done in only four cases; in two because of muscle interposition, and in two because of delayed union. The remaining 20 per cent. were in children, and in these cases adhesive traction was used. In respect to results, the author states that shortening occurred in only eleven cases, the greatest shortening being 1½ inches (3.7 cm.). The average time for return to work at light duty was from 145 to 165 days. The average time lost from full duty was from 195 to 215 days. Sixty-seven per cent. of the patients were previously employed at extremely heavy labor, and of these 90 per cent. returned to their old jobs.

Campbell and Speed [55] also report the end-results in a group of 153 cases of fracture of the femur, sixty-seven being in children under the age of 15 years, and the balance in adults. The treatment employed was

53. Koenig, Fritz: Zentralbl. f. Chir. **52**:883 (April 18) 1925.

54. Conwell, H. E.: Surg., Gynec. & Obst. **40**:112 (Jan.) 1925.

55. Campbell, W. C., and Speed, J. S.: Surg., Gynec. & Obst. **39**:642 (Nov.) 1924.

closed reduction with the aid of an orthopedic table, the patient being under general anesthesia. The unaffected limb was fixed to the foot-piece under moderate traction. The affected limb was flexed to about 45 degrees and moderately abducted. The fragments were next angulated under slight traction until the ends of the bones impinged and could be locked, after which the thigh was gradually straightened until normal alinement was obtained. The position was then verified by roentgen-ray examination and the limb fixed by traction on the foot and countertraction under the knee. A plaster cast was then applied extending from the upper chest to the toes on the affected side and to the knee on the unaffected side. The results in children were fifty-seven, or 87.7 per cent., perfect; six, or 10.5 per cent. good, and one, or 1.8 per cent. poor. In adults, thirty-two, or 60 per cent., were perfect; nineteen, or 55 per cent., were good, and three or 5 per cent., poor. There were no cases of nonunion, and open reduction was not required in any case which came under treatment during the first three weeks after injury. There were twenty compound fractures, of which 50 per cent. healed without infection. The authors feel that autogenous bone grafts constitute the best means of internal fixation in connection with open reductions.

Abbott,[56] writing on the treatment of ununited and malunited fractures of the shaft of the femur by manipulation and caliper extension, states that good results are directly dependent on the efficiency of traction and countertraction. Malunited fractures, even of several months' duration, which show tenderness over the callus, can be refractured by manipulation and pulled down to full length, and union with accurate alinement can be secured by skeletal traction with calipers on a Thomas splint. Manipulation and caliper traction can frequently be used to correct deformity and to promote union in cases of delayed union of the femur. In nonunion it is a valuable adjunct as a preliminary to gain length before operative treatment. He urges that a protective weight-bearing appliance, such as the Thomas walking caliper splint, be accepted as standard in the convalescent treatment of all fractures of the shaft of the femur in adults.

David [57] concludes from an end-result study of fractures of the shaft of the femur in children that compensatory overgrowth after a fracture with shortening in a growing child may be expected to occur and is a factor of importance in limiting operative intervention in such cases. From his observations it appears that alinement of the fragments to prevent angulation and extension to prevent overriding are of greater importance than end-to-end apposition of the fragments. The late

56. Abbott, L. C.: Arch. Surg. 9:413 (Sept.) 1924.

57. David, V. C.: Arch. Surg. 9:438 (Sept.) 1924.

roentgen-ray study of fractures in which no end-to-end apposition was secured shows a restitution to normal of the shaft.

Firor [58] has reviewed the records of all the patients treated in the Johns Hopkins Hospital for recent fractures of the shaft of the femur. It appears from this study that manipulative reduction with immediate immobilization in plaster-of-Paris does not give satisfactory results in patients over 14 years of age, whereas in patients between 7 and 14 years the results are good, and in children under 7 years the results are as good as those obtained by overhead extension. The prime motive underlying the choice of this method of treatment was a desire to reduce the period of hospitalization of such cases, and from this standpoint the results were extremely satisfactory.

[ED. NOTE.—The foregoing reports serve once again to call attention to the difference between fractures of the shaft of the femur in children and in adults. A host of reports has been accumulating to show that in the former compensatory overgrowth and reconstitution of alinement may be expected to occur with growth. In adults, however, the results are universally bad, except with the most careful treatment. In adults the method of treatment now generally advocated is extension, preferably direct skeletal extension, in conjunction with the Thomas splint and the overhead suspension frame. We commend particularly the articles by Conwell and Abbott as showing the possibilities with this method of treatment. The results in adults reported by Campbell and Speed following the use of the reduction and plaster fixation method of treatment are much better than one would expect, judging from the unsatisfactory experience of others with the same method of treatment.]

Fracture of a Single Condyle of the Femur.—Sutcliffe [59] reports a case of complete avulsion of the internal condyle of the femur due to an injury while playing football. Open reduction was performed and the fracture was found to be entirely intracapsular, with the fragment completely separated and displaced backward into the popliteal space. The fragment was replaced and fixed with a small Lane plate. The end-result was complete range of movement and no undue lateral mobility.

Late Posttraumatic Compression of the Os Calcis.—Schurmeier [60] has observed the occurrence of a late compression of the os calcis following previous fracture, and believes the condition is a distinct entity, hitherto unnoted in medical literature. He asserts that it is not merely a compression fracture, as the characteristic roentgenologic findings

58. Firor, W. M.: Bull. Johns Hopkins Hosp. **35**:412 (Dec.) 1924.
59. Sutcliffe, Lionel: Brit. J. Surg., January, 1925, p. 450.
60. Schurmeier, H. L.: J. A. M. A. **84**:80 (Jan. 10) 1925.

appear only late. Many of the cases go unrecognized until an operative procedure becomes necessary. He believes the condition is due to trauma of the blood vessels supplying the cancellous portion of the os calcis, and that it is an identical entity with Kümmell's posttraumatic spondylitis and also probably analogous to Legg's or so-called Perthes' disease.

DISLOCATIONS

Fracture Dislocation of the Neck.—Taylor [61] reports good results following manipulative reduction by a new method in cases of fracture dislocation of the neck. The underlying principle of the method is controlled traction on the head with countertraction on the lower extremities, until the spasmodically contracted cervical muscles have relaxed sufficiently to permit reduction by bimanual manipulation on the part of the operator. With the patient lying on the back, the head supported manually beyond the edge of the table, a traction halter is applied and the traction bands leading from it knotted about the hips of the operator. The latter now grasps the head with his hands, and traction is exerted by leaning backward with the hips. Following reduction, fixation is obtained by a plaster jacket including the head and the neck, the neck portion maintaining extension by pressure upward against the occiput and inferior maxilla, and downward against the shoulders. The support must be worn continuously day and night until solid bony union has occurred between the damaged vertebrae. Physiotherapy and muscle training must be used to obtain the best results.

"Pulled Elbow."—Kervraim [62] gives a new anatomic explanation of the condition of painful pronation so frequently encountered in early childhood. The injury is usually produced by lifting a child by the hand, as in swinging it over an obstacle, or when attempting to prevent a fall. The abrupt traction on the child's forearm, extended in pronation, displaces the synovial pad which then becomes nipped between the head of the radius and the capitellum of the humerus. The sudden pain causes the child to immobilize the arm in pronation. The mechanism is similar to that of luxation of the semilunar cartilage in the knee.

Habitual Luxation of the Shoulder.—Valtancoli [63] discusses the treatment of habitual dislocation of the shoulder as practiced at the Rizzoli Institute. Of fifteen patients that he observed, thirteen were treated by operation. The operation consisted of capsulorrhaphy preceded by arthrotomy. In two cases the anterior wall of the capsule was reenforced by a free transplant of fascia, taken in one instance from

61. Taylor, A. S.: Arch. Neurol. & Psychiat. **12**:625 (Dec.) 1924.
62. Kervraim, Pierre: Presse méd. **33**:84 (Jan. 21) 1925.
63. Valtancoli, Giovanni: Chir. d. org. di movimento **9**:131 (Dec.) 1924.

the aponeurosis of the deltoid and in one from the fascia lata. The results were 86 per cent. cures, with complete function of the joint, 7 per cent. cures with incomplete function, and 7 per cent. failure.

AMPUTATIONS

Bifid Amputation of the Forearm.—Ceballos[64] reports his great satisfaction with a cinematic amputation of the forearm which converted the stump into a two-pronged claw. The distal ends of the radius and ulna were separated and by a plastic procedure covered with skin so as to form two digits about 12 cm. long. By pronation the digits were approximated and by supination they were opened. The patient is now able to write, turn a key in a lock, smoke, or to use a specially constructed knife or fork. The arm is so useful that the patient has given up his originally strong desire for an artificial hand.

[ED. NOTE.—The surgeon who performs an operation of this type assumes a great responsibility, particularly if the patient has only a single amputation. The operation is mutilating and definitely reduces the usefulness of the stump as a support for an artificial limb. To justify it one must be sure that the functional result is measurably better than that obtained with the aid of an artificial hand. The ability to hold a pen or a cigaret with the stump is of no particular advantage to the man with one remaining arm, as he would naturally elect to use the latter for all tasks normally performed with one arm.]

Triple and Quadruple Amputations.—Gale,[65] after a careful review of the literature, has been able to compile eleven cases of triple amputation, in all of which the patients recovered, and six cases of quadruple amputation, in five of which the patients recovered and one died. In one of these cases amputation was done for frost bite; all the rest were the result of railroad accidents. The earliest one he found was reported in 1868. Sixteen of the patients were male and one female. The youngest was 4 years of age. The review of the literature shows that quadruple amputations are very rare and that triple amputations are fairly rare; also that amputations of both types are becoming less frequent. This is due to the many safety devices that have been installed in factories and to the success of the propaganda among working men for "Safety First." He concludes that multiple amputations, when indicated, should be performed simultaneously. This plan requires less anesthetic and permits the patient to be returned more quickly to bed where shock can be combated should it occur, and produces a better result than would be obtained by amputating the most mutilated parts first and then the others if the patient's condition permits.

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64. Ceballos: Presse méd. **33**:60 (Jan. 14) 1925.

65. Gale, S. S.: South. M. J. **14**:48 (Jan.) 1925.

RESEARCH

Effect of Pressure on Articular Surfaces in Pyogenic and Tuberculous Arthritis.—Phemister [66] has made some pathologic and experimental studies in pyogenic and tuberculous arthritis, which if his conclusions are correct must lead to modification of our conceptions of the value of traction in the treatment of these conditions. He draws the following conclusions:

1. In pyogenic arthritis, articular cartilage is killed and broken down first at the points of contact and pressure of opposing articular surfaces.

2. In tuberculous arthritis, articular cartilage is not killed first, but is protected at the points of contact and pressure of opposing articular surfaces. Cartilage is extensively destroyed first along the free surfaces, where the tuberculous granulations can grow into and remove it. It usually disappears last in the regions of contact and greatest pressure in the joint, where it is detached and killed by undermining granulation and is then partly eroded by pressure of opposing bony surfaces.

3. Proteolytic ferments derived largely from polymorphonuclear leukocytes assist greatly in the rapid removal of necrotic cartilage in pyogenic arthritis. Protolytic ferments are absent in tuberculous arthritis, and masses of dead cartilage may persist for months or years, showing few signs of progressive destruction.

4. In pyogenic arthritis the infection rarely invades secondarily the deeper portions of the bone at the points of pressure.

5. In tuberculous arthritis, invasion of the bone at the point of pressure is of common occurrence after the articular cartilage has been largely or wholly destroyed. The invasion is frequently on both sides, in which case it may lead to the formation of kissing sequestra at the points of greatest pressure in the joint.

6. Weight extension should be applied during the active period of pyogenic arthritis to lessen the amount of invasion and destruction of articular surfaces at the points of contact and pressure.

7. On the other hand, it would appear that extension for the purpose of preventing destruction in tuberculous arthritis is not indicated, but when articular cartilage has already been destroyed, extension should lessen the tendency to erosion or invasion with sequestration of bone at the points of greatest pressure in the joint.

Pathogenesis of Skeletal Tuberculosis.—Kolodny [67] has studied the blood supply of the epiphyses of the long bones in relation to the pathogenesis of skeletal tuberculosis and finds parallelism between the

66. Phemister, D. B.: Ann. Surg. **80**:481 (Oct.) 1924.
67. Kolodny, Anatole: J. Bone & Joint Surg. **7**:53 (Jan.) 1925.

frequency with which certain skeletal regions are involved by tuberculosis and the abundance of their blood supply. He concludes that the evidence, both anatomic and clinical, supports the theory that the disease is propagated by the lodgment of bacterial emboli. He points out that trauma plays a certain definite rôle as an etiologic factor in all pathologic conditions of the animal body and that tuberculosis most frequently affects those parts of the skeleton which are especially adapted to the function of support and locomotion of the body and which are under almost permanent physiologic strain. He has injected the blood vessels of the epiphyses with material that is opaque to the roentgen ray, and the article is illustrated by many roentgenograms that demonstrate beautifully the epiphyseal circulation.

Survival of Bone After Removal from the Body.—Haas,[68] continuing his previous experiments, now reports his observations on the survival of bone after removal from the body. He concludes that such bone does not die immediately but that it retains its vitality for varying periods depending on the environment. The degenerative processes can be retarded but not completely suppressed by exposing the bone to a freezing temperature. In order to insure the preservation of the maximum life properties of the bone after removal from the body, it is necessary to maintain it at a freezing temperature. It is also essential that such bone be used at an early time, as the vitality of the osteogenetic cells becomes less as time increases, and is absent after five days.

[ED. NOTE.—Haas's observations are so at variance with the conclusions of other investigators that we must wait for further confirmation before accepting them as definitely established.]

Action Currents Induced by Metal Fixation of Bone.—Orsos,[69] when operating on a fractured humerus, chanced to observe that strong electric currents emanated from the aluminum plate that he was employing for internal fixation when he brought the brass screws in contact with it. When the musculospiral nerve was touched to the plate a strong tetanic contraction of the muscles resulted. At his instigation the amount of the current generated under such conditions was investigated at the Physiologic Institute and found to be about 0.1 milliampere. The considerable strength of this current may be appraised when it is remembered that a current of 1 milliampere is used in dermatologic practice for destruction of the roots of the hair. It is thus evident that marked disturbance in the healing process may be caused by the use of metals of different kinds for internal fixation, and that it is advisable to employ plates and screws of the same metal or of bone.

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68. Haas, S. L.: Arch. Surg. **10**:196 (Jan.) 1925.

69. Orsos, E.: Zentralbl. f. Chir. **52**:1014 (May 9) 1925.

[ED. NOTE.—It is well known that two metals when in contact and in the solution of an electrolyte will set up action currents resulting in electrolysis.]

The Vascular Nerves in Relation to Periarterial Sympathectomy.—Schmidt [70] has performed a series of experiments on dogs to determine whether sympathetic nerves run downward in the coats of the vessels. In one series he cut the femoral artery and sewed it together immediately afterward. In a second series he resected a piece of the artery. In a third he ligated a portion of the artery above and below, but left the intervening portion in contact with the surrounding tissues. In a fourth series be entirely freed a certain length of the artery from its accompanying tissues. By this means he hoped to study the interruption of nerve currents along the vessels and that of nerves reaching the artery from the neighboring tissue. Specimens were taken for histologic examinations from six to eight months after the operation. Capillary microscopic studies showed a certain state of contraction persisting for about three months after the operation, followed by a return to normal conditions. His conclusions are that no nerves run distally in the vessels but that the nerves reach the vessels from the neighboring tissues. Vasoconstrictors and vasodilators run with the great nerves, but not with the great vessels.

Radicular Nerve Anastomosis.—Crescenzi [71] reports the results of experimental anastomosis of the spinal nerve roots in ten dogs. The nerves used were the lumbar and first sacral nerves. Both end-to-end and lateral anastomoses were made, also homolateral and contralateral. All were successful, a result he explains by the fact that the sutures were made in nerve roots that were normal. His conclusions are that:

1. It is a matter of indifference whether the nerve root furnishing the graft is situated above or below the nerve root to which the graft is given.

2. The graft may be taken from a root arising on the opposite side of the cord.

3. In lateral anastomoses it is possible under certain conditions to have newly formed nerve fibers running both centrifugally and centripetally in a given nerve.

4. One group of anterior horn cells can innervate several distinct muscle groups, either contralateral or homolateral.

Elasticity of the Capsule and Ligaments of the Knee.—Katzenstein and Fecher [72] have made elaborate investigations of the elasticity of the

70. Schmidt, A.: Beitr. z. klin. Chir. **133**:131, 1925.

71. Crescenzi, Giulio: Chir. d. org. di movimento **9**:28 (Dec.) 1924.

72. Katzenstein, M., and Fecher, K.: Arch. f. klin. Chir. **130**:1, 1924.

capsule and collateral ligaments of the knee, and have come to the following conclusions: The greatest degree of elasticity is found in men between the ages of 20 and 40 years. The asthenic type is much inferior to the normal type, a fact that may be of importance in regard to enteroptosis and flatfoot, as it is easy to imagine that all the ligaments may be of corresponding poor quality. Serious disease of long duration, such as tuberculosis or rickets, reduces the elasticity of the ligaments. The right side is inferior to the left.

Physiologic Effect of Massage.—Pemberton, Cajori and Crouter [73] have studied the physiologic effect of massage. They point out that Barr has shown that exercise is accompanied by a state of affairs that is opposite to that induced by exposure of the body to heat. Actively contracting muscles produce lactic acid in amounts sufficient to change the reaction of the blood for as much as fifty minutes. In view of the opposite effects of these two measures it seemed desirable to analyze the effects of massage on the blood and urine. From their statistics they reach these conclusions:

1. Massage of voluntary muscles, even though vigorous, is not accompanied by the evidences of lactic acid production and acidosis that accompany relatively mild active exercise of short duration or by the evidence of loss of acid and alkalosis that follow exposure of the body to external heat.

2. Massage can be used as a partial substitute for active exercise in many conditions, but its benefit must be due chiefly to some mechanism other than that reflected in the chemical changes accompanying exercise. The available evidence suggests that these benefits are referable to changes in the circulation, especially capillary.

3. The favorable influence on the rheumatic syndrome of exposure to internal heat, massage and active exercise apparently find their chief explanation in their influence on the circulation, including the capillary beds, the corollary part of the underlying pathologic change in arthritic conditions.

MISCELLANEOUS

Surgical Repair of Peripheral Nerves.—Delagenière [74] reports the end-results from operation in a series of 375 cases of nerve lesion. The operative procedures were: surgical neurolysis, 113; resection and suture, 236; nerve grafts, nine, and resection and immediate suture for causalgia, seventeen.

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73. Pemberton, Ralph; Cajori, F. A., and Crouter, C. Y.: J. A. M. A. **83**:1761 (Nov. 29) 1924.

74. Delagenière, H.: Surg., Gynec. & Obst. **39**:543 (Nov.) 1924.

The operation of neurolysis did not give good results except in cases in which there was simple compression without demonstrable damage to the nerve. Of the 236 nerve resections followed by suture, there was one group of 142 cases in which the suture was performed correctly, that is to say it conformed to the anatomic and physiologic requirements for reconstruction of the nerve. There was a second group of ninety-four cases in which the suture was performed incorrectly or in which poor technic was employed. The 142 correct sutures have resulted in 122 complete successes (85.9 per cent.), sixteen partial successes, and four failures. On the other hand, the ninety-four incorrect sutures have given only six complete successes, thirty-seven partial successes, and fifty-one failures (54.2 per cent.). Delagenière emphasizes the following points:

1. The earlier the suture is performed the more rapid the regeneration. The correctness of this statement is proved by the uniform success obtained in the cases of causalgia treated by resection and immediate suture and by the cases in which suture was performed immediately after injury.

2. In the cases of delayed suture, although the regeneration is delayed, the final recovery should be just as complete. The writer reports a successful result in one case in which suture was performed as late as twenty-eight months after the injury. No matter how old the wound, he considers it worth while to try operative repair.

3. The regeneration appeared to be much quicker when there was complete physiologic interruption but no separation of the ends of the nerve. Regeneration was less rapid when there was separation of the nerve ends or when the distal segment was markedly disorganized.

4. The radial, musculocutaneous and external popliteal nerves regenerate most quickly. The internal popliteal, ulnar and median nerves regenerate with greater difficulty. This is due to the fact that there is a greater number of sensory fibers included in the nerve structure and that there is greater chance for aberration of the motor fibers into the sensory channels and vice versa. The writer reports uniformly good results in cases of causalgia following division of the nerve and immediate suture. The purpose of this operation is to give the nerve a complete rest so that it may be cured of its inflammation. This requires a long time (one year at least), but in spite of this delay the causalgia is relieved when the regeneration occurs.

Myositis Ossificans.—Noble [75] has analyzed eighteen cases of myositis ossificans seen in ten years at the Mayo Clinic. In the cases reported in the literature the great majority are in men in early adult

75. Noble, T. P.: Surg., Gynec. & Obst. **39**:795 (Dec.) 1924.

life. In the writer's series thirteen were males and five females. Fifty per cent. of them occurred between 15 and 25 years, the extremes being 12 and 52 years. None of the theories of etiology appear to explain all types of the condition. The evidence seems to point to a combination of a mechanical factor and an ossifying diathesis as described by Virchow as the underlying causes. The differential diagnosis between this condition and sarcoma is not always clear, and the possibility of error must be borne in mind. Myositis ossificans is comparatively rare. It follows both open and closed trauma, occurs after acute infection, and spontaneously when there has been no history of infection or trauma. The most common sites are the quadriceps and brachialis anticus. In the early stage the treatment is rest and fixation. Operation should only be considered after the lapse of six months and when there is definite functional disability.

Fat Deposits in Subdeltoid Bursitis.—Stern [76] reports three cases of subdeltoid bursitis in which the roentgen-ray examination showed the typical calcium deposit in the supraspinatus tendon. In each case the symptoms became so severe that operative intervention was indicated. There was found at operation in all of the cases a small, oblong, encapsulated tumor, soft but nonfluctuating, located in or on the supraspinatus tendon and its insertion in the greater tuberosity. When opened it was found to contain a granular, noncrystalline, brownish gray substance, which on chemical examination was found to be amorphous fat. No bony or calcium deposit could be found, and the subsequent roentgenograms showed that the shadow had disappeared.

76. Stern, W. G.: Surg., Gynec. & Obst. **40**:92 (Jan.) 1925.